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IMPLEMENTATION OF THE ACID PRECIPITATION ACT OF 1980

HEARING

BEFORE THE

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

NINETY-EIGHTH CONGRESS

SECOND SESSION

ON THE

IMPLEMENTATION OF THE ACID PRECIPITATION ACT OF 1980

APRIL 30, 1984

Printed for the use of the
Committee on Energy and Natural Resources

U.S. GOVERNMENT PRINTING OFFICE
36-952 O WASHINGTON : 1984

S311-58

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IMPLEMENTATION OF THE ACID PRECIPITATION ACT OF 1980

MONDAY, APRIL 30, 1984

U.S. SENATE,
COMMITTEE ON ENERGY AND NATURAL RESOURCES,
Washington, DC.

The committee met, pursuant to notice, at 10 a.m. in room SD-366, Dirksen Office Building, Hon. James A. McClure, chairman, presiding.

Present: Senators McClure, Warner, Hecht, Evans Johnston, and Ford.

Also present: Richard D. Grundy, budget officer and professional staff member; Terri Sneider, counsel; Elizabeth Moler, counsel for the minority; and Linda Mason, professional staff member for the minority.

OPENING STATEMENT OF HON. JAMES A. McCLURE, A U.S. SENATOR FROM THE STATE OF IDAHO AS PRESENTED BY SENATOR HECHT

Senator HECHT [presiding]. Good morning.

The Committee on Energy and Natural Resources will convene. Senator McClure has been temporarily delayed in traffic and will be arriving momentarily, but because we have some U.S. Senators who wish to make some opening remarks, we will commence.

Before hearing from them, I will read Senator McClure's opening statement.

Acid precipitation and the use of fossil fuels. Good morning.

Today, the committee reconvenes oversight hearings on acid rain and the use of fossil fuels. This hearing was requested by eight members of the committee, by letter of February 22, in recognition of pending legislative initiatives in both Houses of the Congress which would impose substantial new regulatory requirements on coal-burning facilities, in response to acid rain concerns.

[Subsequently, the text of the letter was submitted for the record:]

PRIORITY

[illegible]

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United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

Official Committee [illegible]

February 22, 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
MAR 1 1984

The Honorable James A. McClure
Chairman, Senate Energy Committee
Washington, D.C. 20510

Dear Mr. Chairman:

During the last two Congresses, the Committee has conducted hearings on the phenomenon of acid rain and its implications for national energy policy. The acid deposition control programs currently being considered by other committees of the Senate will have significant impacts upon the cost of electricity generation, as well as upon the production, distribution and utilization of our nation's fossil fuel reserves, including coal. These issues clearly fall within the jurisdiction of our committee.

During his recent state of the union message, the President indicated his support for increased Federally sponsored research into the acid deposition phenomenon, and for the development of technologies that will allow our nation's coal reserves to be burned more cleanly. Such a proposal is of obvious importance to the responsibilities of our committee for energy research and development programs.

On August 19, 1982, the Committee conducted an oversight hearing on "Acid Precipitation and the Use of Fossil Fuels." Since that hearing, a number of significant developments have occurred regarding acid precipitation. Perhaps most importantly, both the National Academy of Sciences and the Environmental Protection Administration have released major assessments of the present state of scientific knowledge concerning the relationships between the emission of precursor gases, such as sulfur dioxide, and the occurence of acid precipitation.

We encourage you, Mr. Chairman, to schedule oversight hearings on the acid deposition issue as it relates to the production, distribution and use of our nation's coal and other fossil fuels as well as the nature and scope of our fossil fuel research and development programs. We suggest that the hearings review the the present state of scientific knowledge concerning the phenomenon of acid precipitation, the progress that is being made under present law to reduce emissions from fossil fuel combustion, and the available alternatives for further reducing such emissions. The hearings would also give the Committee an opportunity to evaluate any legislation pending before it on this subject.

Because members of the Committee will soon have to make decisions regarding energy research and development and other programs related to the acid rain problem, we hope these hearings can be held in the near future.

Sincerely,

John Warner
J. Bennett Johnston

Wendell Ford
John Melcher

John Heinz
Don Nickles

Dale Bumpers
Bill Bradley

Senator HECHT. This hearing also is a continuation of committee interest in energy and environmental issues which date from the 93d Congress with enactment of the Energy Supply and Environmental Coordination Act of 1975. That statute, which promoted greater use of coal in lieu of oil imports, was followed by the Fuel Use Act and the Energy Security Act in the 96th Congress, and oil backout legislation, which passed the Senate, also in the 96th Congress.

Each of those earlier legislative initiatives recognized that any serious consideration of a national policy to foster greater use of domestic fuels in our Nation's energy economy must, necessarily, reflect consideration of the relationship between fossil fuel usage and environmental requirements.

When those measures, and the Clean Air Act, were considered by the Congress, both our national energy and environmental policies were in the early stages of their formulation. Today, by comparison, our legislative efforts are directed toward the refinement of already-existing policies. Current effort seeks to achieve more cost-effective mechanisms to the achievement of environmental requirements, but each new increment of control is increasingly more costly to accomplish. And, the control of acid precipitation is such a situation.

In recognition that the effect of acid deposition is a potentially serious environmental concern, in 1980, the Congress enacted the Acid Precipitation Act. That act established a comprehensive 10-year Federal research program to be administered by the Interagency Task Force on Acid Precipitation, which is represented here today.

Already, results of efforts of the task force indicate that in 1980 we did not sufficiently understand the causes of acid precipitation, or the resultant effects, to have then formulated an effective and cost-effective control strategy. Similarly, because of the efforts of the task force and the National Academy of Sciences, it is apparent that only now are we beginning to understand the related environmental transport mechanisms. Numerous uncertainties, however, still surround our understanding of these mechanisms. The recent debate between the National Academy of Sciences and the National Laboratory Consortium emphasize the pressing need for additional research.

[Subsequently the following joint NAS-NLS statement was submitted for the record:]

Relationship Between the Calvert Committee (NAS) Report "Acid Deposition: Atmospheric Processes in Eastern North America" and the National Laboratories' Critique

The criticisms of the recent NAS report expressed by the group of scientists at national laboratories appear to be more a matter of emphasis than of fundamental differences in sources of data or in interpretation.

Both the national laboratory critique and the NAS report agree that in general the detailed processes involved in acid deposition are inherently non-linear. The NAS committee expressly set out to determine the extent of the non-linearities. It found that sufficient data for the analysis were available only for assessing relationships between long-term (annual) average values of emissions and deposition integrated over large spatial scales. Several lines of evidence and theoretical calculations suggest that if non-linearities exist between annual average emissions and deposition over large areas, they are not dominant. The NAS report phrased its conclusion as "there is no strong evidence that the relationship is non-linear" because the data are not sufficient to prove the relationship is linear. The data can only be used to assess the strength of the non-linearity.

The NAS report points out that short-term events (episodes) are very complex and may indeed involve non-linearities. Non-linearities clearly arise, for example, in short-term meteorology and may be important for chemical processes taking place in clouds in winter. When the individual episodes are summed or averaged over the year, however, the non-linearities appear to balance out, or in the case of cloud processes in winter, apparently do not contribute much to annual totals.

Both the NAS report and the national laboratory scientists agree that further research on atmospheric processes is crucial to advancing our knowledge of the phenomenon of acid deposition. If we are to improve our ability to construct computer-based models useful for predicting the consequences of alternative emission control strategies, we need to study the detailed processes that occur on short temporal and spatial scales, where non-linearities can be expected. Only by building up this area of understanding can we have confidence that the models accurately reflect what is happening in nature and that reliable projection of the specific consequences of targeted emission reductions can be made.

The NAS report asserts that current models are not sufficiently tested to be relied upon for quantitative evaluations of the consequences of targeted control strategies. This conclusion is, of course, a matter of judgment.
Dr. Calvert, chairman of the NAS committee, has suggested in congressional testimony that current models can make, and have been used to make broad-based qualitative comparisons that have provided useful contributions to the policy debate.

The seeming conflict between the NAS committee report and the comments of the National Laboratory Consortium's scientists is therefore more apparent than real, resting mainly on different approaches.

This statement was reviewed by Dr. Calvert (NAS) and Dr. Manowitz (NLC) and is agreed to represent an accurate and reasonable description of the situation.

Senator HECHT. Because of the limited data currently available, there is a reasonable basis for legitimate differences in interpretation among recognized experts.

This is reflected in their joint statement. Precisely for that reason, a vigorous research effort by the task force authorized by the Energy Security Act is needed to address these scientific uncertainties.

President Reagan recognized this in his state of the Union address this year when he proposed to double the current Federal funding for this effort from $27.5 million in fiscal year 1984 to $55.5 million in fiscal year 1985.

[Subsequently the following table was inserted for the record:]

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

President's Budget Request
FY 1985
($ in thousands)

		USDA					DOI					
	EPA	CSRS	ARS	FS	NOAA	DOE	PS	GS	FW	BLM	TOTAL	%
A. Natural Sources					855						855	1.5
B. Man-made Sources	1200					750					1950	3.5
C. Atmospheric Processes	10,576				1005	5260					16,841	30.3
D. Deposition Monitoring	4357	248		146	500	977	322	1870		80	8500	15.3
E. Aquatic Effects	8022			210		150	148	645	1525		10,500	18.9
F. Terrestrial Effects	5610	1045	384	1756		120	329	486			9732	17.5
G. Effects on Materials	975						970	150			2095	3.8
H. Control Technologies	600										600	1.1
I. Assessments and Policy Analysis	3025					1400					4425	8.0
Subtotals:		1293	384	2114			1769	2951	1525	80		
TOTALS:	34,365		3791		2360	8657			6325		56,498	
(%)	(61.9)		(6.8)		(4.3)	(15.6)			(11.4)			

PROGRAM DESCRIPTION

The National Acid Precipitation Assessment Program is designed to successively improve our understanding of the causes, effects and possible solutions to the acid rain problem. The Program includes research, monitoring and assessment activities that emphasize the timely development of a progressively firmer scientific basis for decision making by the Congress, regulatory agencies, natural resource managers, private sector managers, environmental groups, and the public. The National Program consists of over 200 interrelated projects, which are funded by several Federal agencies, in nine major research categories including natural sources, man-made sources, atmospheric processes, deposition monitoring, aquatic effects, terrestrial effects, effects on materials, control technologies, and assessments and policy analysis. Hundreds of scientists in government, academia, and the private sector are involved in the National Program.

PROPOSED CHANGE

In FY 1985, the President's budget request for this comprehensive national research program is $55.5 million, or a 100% increase over the FY 1984 budget of $27.5 million. This increase in funds reflects important research priorities, and accelerates the rate at which scientific uncertainties are narrowed so that the pressing policy questions can be addressed more adequately.

RATIONALE

In addition to the ongoing base research in FY 1984, the major new initiatives proposed for FY 1985 include the following:

- Major Atmospheric Study: The Environmental Protection Agency, the Department of Energy, and the Electric Power Research Institute are cooperating in planning a large-scale, comprehensive atmospheric field study. The FY 1985 funding will be used to complete experimental designs, validate instruments, and field test sampling protocols and tracers. ($7650K)

- Wet and Dry Deposition Monitoring: The number of wet deposition monitoring stations will be increased significantly, and the dry deposition methods research and development will be accelerated. Dry deposition process studies will also be undertaken to support the establishment of future dry deposition monitoring stations. ($500K - wet; $1000K - dry)

- Liming Studies: A feasibility study on the benefits and limitations of lake liming as a possible mitigation strategy will be initiated in FY 1985. These research and demonstration projects are necessary prior to any possible field applications in order to study the range of different liming options, and their physical and biological effects on acidified aquatic systems. ($1000K)

- Ecological Monitoring Program: The ongoing long-term monitoring program will be expanded to include more intensive ecological monitoring, so that a change can be observed at a more detailed level, thereby increasing the ability to understand the processes as well as the ability to detect change. This part of the ongoing effort is needed to intensively monitor the environment to observe relationships between deposition and aquatic and terrestrial effects in the areas of the country that are believed to be sensitive to acidic inputs. ($3000K)

- Surveys of Lakes and Streams, and Forests: In FY 1985, the initial planned lake survey will be expanded to include several hundred streams, as well as fisheries in a select number of lakes. The purpose of the national lakes survey is to quantify the current water chemistry of lakes and streams, determine the status of fisheries and other biotic resources, and select regionally representative surface waters to quantify future changes in aquatic resources through a long-term monitoring system. ($2000K)

  Also in FY 1985, a national survey of forest damage and sensitivity will be initiated. In order to fill other critical gaps in forestry research, studies on soil processes and field effects will be enhanced. The data provided by these surveys will be essential to a better understanding of the existing and potential extent of the acid deposition problem. ($3000K)

- Field Exposure of Materials: The program on field exposure of materials will be expanded in FY 1985 to address the problem of multiple pollutants attacking construction materials. The study of the effects of acid deposition on materials is another important aspect of the ongoing national research program.

- Control Technologies: In FY 1985, the National Program includes funds for analyses of specific control technology issues important to acid deposition. (However, hardware development for the control of SO_2 and NO_x is funded under pre-existing programs at EPA, DOE and TVA.) In FY 1985, studies will be initiated on assessing the potential for control of directly emitted acid materials, and on technology combinations and modifications for moderate SO_2 control at a low cost. The Limestone Injection Multistage Burner (LIMB) is one promising new technology for the control of both SO_2 and NO_x, which eventually could provide more cost-effective methods of controlling acid deposition precursors. ($600K)

- Current Damages Assessment: One of the important milestones of the National Program is an assessment of the magnitude of current damages from acid deposition, and estimates of the uncertainties associated with the source/receptor relationship. This major assessment is underway and should be completed in FY 1985.

EFFECTS OF PROPOSED CHANGE

This increase in the budget of the National Program will enhance the effort to resolve the key scientific questions, such as determining long-term, biological and ecological effects, and understanding the complex physical, chemical and meteorological relationship. In FY 1985, the additional resources will be used to initiate the large-scale atmospheric field study and enable a more complete understanding of the source/receptor relationship. The increased emphasis on surveys of sensitive aquatic and terrestrial resources are essential for the comprehensive damage assessment due in FY 1985, and will ultimately refine our knowledge of the cause and effect relationships. It will require a sustained and systematic effort over the coming years to significantly reduce the major uncertainties about the causes, effects, and management of acid deposition.

Senator **Hecht**. This task force effort is directed at developing—and as expeditiously as possible—the information needed by policymakers to formulate appropriate actions to deal with acid precipitation.

Among other factors, this hearing will explore the advances that have been made in the state of our scientific knowledge with respect to: First, the causes and effects of acid precipitation; second, the adequacy of current knowledge in advancing solutions to the problem; and, third, the energy and environmental implications of legislating now in advance of further implementation of the Interagency Task Force Plan.

The **Chairman** [Senator McClure presiding]. Thank you, Senator Hecht.

Senator Ford.

[Subsequent to the hearing the chairman requested the Congressional Research Service to prepare a summary of the record. See Senate Print No. 98-217, which is printed as a separate document.]

STATEMENT OF HON. WENDELL H. FORD, A U.S. SENATOR FROM THE STATE OF KENTUCKY

Senator **Ford**. Thank you, Mr. Chairman.

My opening statement this morning is not going to be long, because my position on the very real problem of acid rain deposition is already clear on the record.

I strongly support the President's approach of further research before corrective action is taken. I am an original cosponsor of Senator Byrd's bill, S. 454, which, recognizing that controls on fossil fuel today would be premature, also calls for extensive research and proposes money from the mitigation of the effects of acid deposition on lakes and streams, as does the President's.

And I enthusiastically endorse S. 1925, the coal technology bill introduced by Senator Byrd that is designed to promote the clean burning of coal, our most abundant natural energy resource.

As the scientific community continues to study the causes and effects of acid rain, more and more evidence questions the hypothesis of most of the legislative proposals before the Congress, that is the long-range transport of sulfur dioxide from coal-burning Ohio Valley that is the culprit.

I believe that this hearing today will further underscore the fact that all the answers are not yet in; that it is far from assured that an emissions control system will result in a reduction of acid deposition in New York and New England. And that, quite frankly, we are missing some important pieces of the acid rain puzzle.

Thank you, Mr. Chairman.

The **CHAIRMAN**. Thank you, Senator Ford.

Senator Evans.

Senator **EVANS**. No.

The **CHAIRMAN**. Senator Hecht.

Senator **HECHT**. No statement.

The **CHAIRMAN**. Our first witness this morning, we're glad to have the distinguished Democratic leader this morning as our leadoff witness. We'll hear from the Honorable Robert C. Byrd.

STATEMENT OF HON. ROBERT C. BYRD, A U.S. SENATOR FROM THE STATE OF WEST VIRGINIA

Senator **BYRD**. Thank you, Mr. Chairman.

I commend you for scheduling this hearing, and I thank you for providing the opportunity to those of us who are proponents, as well as opponents of legislation and various types of measures that have been introduced and for giving us an opportunity for expressing our views on this important issue.

The issue of acid deposition is one of the most complex and divisive policy issues of the 1980's. To date, about 15 bills have been introduced in this Congress to address the problem of acid rain.

Most of these proposals would mandate substantial reductions in sulfur dioxide from coal-fired powerplants in the Midwest and Appalachia in the belief that they are the cause of the acid rain problem in the Northeast and Canada.

Recently, the National Governors' Association formally adopted a position which calls for a reduction in sulfur dioxide emissions of 10 million tons in the eastern United States within a 13-year period.

The Senate Committee on Environment and Public Works recently reported a bill, S. 768, which mandates a 10-million ton reduction in sulfur dioxide emissions over a period of 10 years, largely from coal-fired powerplants in the Midwest and Appalachia.

Proposals such as these are estimated to cost billions of dollars, not to mention the higher utility bills to consumers, and thousands of jobs in West Virginia and in other States.

The costs are staggering. In West Virginia alone, according to a report by the Congressional Research Service, as many as 24,550 jobs could be lost as a result of sulfur dioxide control legislation.[1]

Many of these proposals would allow utilities to choose the least-cost method, so-called, for achieving any mandated reductions in sulfur dioxide emissions.

That is, utilities would not be required to install flue gas desulfurization equipment, so-called scrubbers, to achieve any mandated emission reductions.

Proponents of such an approach suggest that utilities should be allowed to choose the least-cost method for achieving emission reductions. This usually means switching to low-sulfur coal.

To the extent that utilities switch to low-sulfur coal rather than install the flue-gas desulfurization units—in other words, scrubbers, the demand for such coal would increase.

This would create jobs, they say, in the low-sulfur coal industry. According to this theory, the employment impacts of fuel switching on the high-sulfur industry could be offset by the employment gains in the low-sulfur industry.

Thus, it has been suggested that States such as West Virginia will experience a net gain in employment. That is, the number of jobs created in the State's low-sulfur coal fields will be sufficient to offset the jobs lost in the State's high-sulfur coal fields.

Several months ago, I asked the Congressional Research Service to prepare a report analyzing the impact of acid rain legislation on the eastern low-sulfur coal industry and its markets.

The report, titled "Acid Rain Legislation and the Future of the Eastern Low-Sulfur Coal Industry," provides valuable information and makes several important points which I would like to bring to the attention of the committee.

The report suggests that the increase in eastern low-sulfur coal demand that has been estimated by some analyses may have been overstated.

The CRS report indicates that the demand increase from acid rain legislation would be in the lower-half of a range of from 35 to 50 million tons.

This is half the amount suggested by some analyses of the least-cost approach. These lower demand figures suggest less eastern low-sulfur coal production, and lower employment gains in the low-sulfur coal fields than estimated by least-cost analyses.

In fact, the report points out that the net 1993 production in central Appalachia could be no greater than would be expected with no acid rain legislation.

In short, the CRS report casts doubt on the prospects for a net employment gain in such States as West Virginia as a result of a least-cost approach.

The least-cost approach would allow utilities to switch to low-sulfur coal, which is less expensive than installing scrubbers.

It is often assumed that electricity consumers will benefit from such an approach because their utility bills would not be as high as they would be if the utility had installed scrubbers.

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[1] See appendix A.

However, the CRS report raises some questions about this assumption. The report points out that consumers are the last link in the coal supply chain from mining to preparation, transportation, and to conversion.

Thus, although the cost of low-sulfur coal at the mine is less than the cost of installing a scrubber, the delivered cost of low-sulfur coal to a utility could be substantially higher as a result of increased cost at the various points along the supply chain; for example, increased rail rates for coal transportation.

Increased costs to the utility in turn would reduce any cost differential between fuel switching and installing scrubbers.

Thus, the CRS report suggests that estimates of cost differences between least-cost approaches and technology-based acid rain strategies may be significantly overstated from the viewpoint of electricity consumers.

Consumer savings is the primary reason for accepting the significant economic dislocation in high-sulfur coal regions resulting from a least-cost approach. If the savings do not accrue to electricity consumers, then those consumers may be only marginally better off than under a more technologically based approach, while the adverse impacts of the least-cost strategy on the high-sulfur coal industry would remain just as severe.

This is a highly abbreviated summary of an extensive, complex analysis. It is an excellent report, and I commend the Congressional Research Service for its work.

Let me say at this point that the debate over least-cost versus technology-based approaches is premature. It presupposes that the scientific debate is over. Major areas of scientific uncertainty need to be addressed before there is an adequate basis for determining whether there is a need for such costly measures.

Scientists are far from unanimous on the issue of whether massive reductions in sulfur dioxide emissions from powerplants in the Midwest and Appalachia will reduce acid deposition in the Northeast.

The National Academy of Sciences concluded, in its often-misconstrued report on acid rain, that, quote, "the relative contributions of specific source regions to specific receptor sites currently remain unknown."

"Furthermore,"—and continuing to quote, "we cannot objectively predict the consequences for deposition in ecologically sensitive areas of changing the spatial pattern of emissions in eastern North America, such as by reducing emissions in one area by a larger percentage than in other areas."

This suggests, Mr. Chairman, that current sulfur dioxide control proposals would be of questionable effectiveness, and would impose enormous costs to achieve speculative environmental benefits.

The crux of the acid rain debate is whether we need to require significant reductions in sulfur dioxide emissions over and above the requirements of the Clean Air Act.

In fact, the Clean Air Act is an effective long-term program to control such emissions. Under current law, over the next 20 years, total sulfur dioxide emissions from all sources in the Eastern United States are projected to remain constant, and then to decline after the year 2000.

Subsequent to the passage of the Clean Air Act, significant progress has been made in controlling sulfur dioxide emissions. For example, recent estimates by the Environmental Protection Agency indicate that, on a national basis, sulfur dioxide emissions declined 25 percent between 1970 and 1982.

During the same period, coal consumption by the electric utility and industrial sectors increased 38 percent. Coal consumption by the electric utility sector alone increased 85½ percent during this period.

So before Congress mandates additional sulfur dioxide reductions on the order of 10 to 12 million tons above and beyond the requirements of current law, prudence dictates that the uncertainties about the causes and the consequences of acid deposition be addressed as quickly as possible. Equity dictates that we carefully weigh the enormous costs against any benefits that may or may not accrue from the imposition of additional controls.

Indeed, there is evidence that there has been little change in the acidity of precipitation in the Northeastern United States, and that acidification may have abated.

A 1982 report, based on 15 years of data collected by the U.S. Geological Survey, indicates that the acidity of precipitation in New York has not changed since 1965. Sulfate concentrations in New York precipitation and in streams in parts of the State were decreased an average of 1 to 4 percent per year between 1965 and 1978.[1]

A more recent USGS study found that increases in the acidity of precipitation in New England and New York occurred, quote, "primarily before the mid-1950's." However, "since the mid-1960's there's been no significant change in the acidity of precipitation in this region." [1]

The study also reports findings on acidification trends in Canada and other regions of the United States, quote, "In southeastern Canada, the best-documented cases of acidified lakes point to localized sources of acidic emissions as the cause. Sparse evidence of recent regional acidification of lakes and streams exists, but evidence for acidification of precipitation as the cause is largely lacking. In the Southeastern United States, most data on acidification of surface waters are ambiguous, and in the West, most of the data reflect local conditions," close quote.

This suggests that local sources of acid rain precursors, rather than midwestern and Appalachian sources, may play an important role in the acidification of lakes and other surface waters in parts of the United States and Canada.

This is not to say that acidification of surface waters is not a problem. However, reliable documentation of the extent of the problem is limited, though there is evidence which is suggestive.

For example, a 1980 study by the New York State Department of Environmental Conservation indicated that between 1975 and 1979, surveys had been conducted for 849 of the 2,877 lakes and ponds in the Adirondacks. The 849 lakes accounted for 29.5 percent of the total number of lakes, and about 80 percent of the total surface acreage of such waters.

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[1] See appendix A.

According to the report, 212 lakes were found to be acidified; in other words, with a pH factor of 5 or less. These lakes accounted for 4.7 of the surface acreage included in the study.[1]

In addition, we should keep in mind that many scientists tell us that our knowledge of past, current, and future acidification trends of critical processes that control acidification and of the degree of permanency of biological effects remains incomplete and subject to debate.

It is also alleged that acid deposition is causing extensive damage to forests, plants, crops, and building materials.

The Environmental Protection Agency has completed an extensive review and assessment of the scientific literature on the causes and environmental consequences of acid rain.

The results of this review have been published for public review in a massive two-volume report, entitled "The Acidic Deposition Phenomenon and its Effects."

This report, known as "Critical Assessment Document," clearly demonstrates that the scientific evidence is far from conclusive, because the relationship between acid deposition and environmental effects is highly complex and only partially understood.

But the EPA review does include the following:

1. There is no direct evidence that acidic deposition is responsible for the reductions in tree growth occurring in North America and Europe;

2. Acid deposition may stimulate, retard, or have no apparent effect on plant growth and development;

3. Many crops studied in various experiments exhibit no effect on growth or yield as a result of exposure to simulated acid deposition. Some species are affected positively, while other species are affected negatively; and

4. Damage to building materials in urban areas is believed to be due more to local pollutants than to acid rain from the long-range transport of pollutants from other regions.

Thus, the scientific debate over acid rain is far from over. Nevertheless, proponents of stringent controls continue to accuse those who advocate a prudent approach of doing nothing. Nothing could be further from the truth.

In 1980, the Congress recognized the problem of acid deposition and acknowledged the need for a more complete scientific understanding of the acid deposition phenomenon.

Thus, Congress enacted the National Acid Precipitation Assessment Act which established an Interagency Task Force on Acid Precipitation and an extensive assessment program.

The program established under the act engages the scientific capabilities and resources of 12 Federal agencies, and has a total budget in fiscal year 1985 of $55.5 million.

Based upon this work, the Task Force on Acid Precipitation will make a report to Congress no later than 1992. The report will provide a more complete scientific basis for addressing the acid deposition problem in a manner that minimizes costs and optimizes benefits.

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[1] See appendix A.

Proposals to impose a massive new regulatory program prior to the task force report prematurely prejudge the outcome of the task force efforts.

Legislation has been introduced, to which you have alluded, Senator Ford, S. 454, and of which you are the leading cosponsor, which would mandate an acceleration of the task force efforts and require that the task force report to Congress before 1992.

The legislation also provides a program of grants to States to demonstrate mitigation techniques; for example, lake liming, for sensitive areas affected by acid deposition.

This has the virtue of promoting direct remedies to the problem at far lower costs. Considering the scope and magnitude of the Federal acid rain assessment, surely it is hyperbole to characterize a prudent approach as a do-nothing approach.

Legislation has also been introduced, S. 1925, to establish a 5-year program to accelerate the development of new and advanced technologies to allow for the expanded use of all the Nation's coal reserves in an environmentally acceptable manner. And here again, you are cosponsor, Mr. Ford.

This legislation recognizes that a program is needed to address the technological challenges to future coal use raised by the acid rain debate.

As has been pointed out, President Reagan, as indicative of his position in the matter, stated an approach during his address to the House and Senate at the beginning of the year, pursues this same approach; in other words, have more research, collect more data before—in other words, look before we leap and, in the meantime, proceed with research and development that will lead to a process in the combustion of coal that would be environmentally approved.

On April 9, the Subcommittee on Research and Development held hearings on the coal combustion research and development legislation, and I was encouraged by the supportive testimony provided by many of the witnesses.

Surely, the advocates of sulfur dioxide controls do not consider the establishment of such a program as a do-nothing program, if they carefully examine the facts.

We should not rush to embrace a massive new regulatory program so that we may just appear to be doing something. We should not be pursuing policies which will render large segments of the Nation's coal reserves unmarketable.

We should be pursuing policies which will enable us to maximize the potential of all our coal reserves, while meeting the Nation's environmental goals.

We should be pursuing policies which would preserve jobs, and not jeopardize them.

We should be trying to create new jobs, not threaten the economic future of States such as West Virginia for the sake of, quote, doing something, close quote, about the acid rain problem.

The approach that I advocate, and which is advocated by the President of the United States, is deliberate and reasonable. It allows for the timely development of an adequate scientific basis for effective action, and promotes the development of advanced coal technologies to allow the expanded use of the Nation's vast coal reserves, without causing substantial economic and employment dislocations.

Mr. Chairman, this concludes my statement. I have alluded to several documents in the presentation of my statement. I ask unanimous consent of the committee that I may submit these documents, and other appropriate materials for the record.

I also thank Senator Mitchell for allowing me to precede him. And I commend him on his strong position—which in many ways probably differs from mine, but at the same time, I recognize the necessities that bring that about.

That concludes my statement.

The CHAIRMAN. Thank you, Senator Byrd.

The various documents to which you have referred will be received for the record or for the file, according to the nature of the documents.

Are there any questions of Senator Byrd?

Senator FORD. I have no questions.

Senator EVANS. No questions.

Senator HECHT. No questions.

The CHAIRMAN. Thank you very much for a comprehensive statement, Senator Byrd.

Of course, you're free to remain, if you desire to do so, and hold your colleague to your right down a little in his testimony, perhaps, or you can leave and allow him free reign.

Senator BYRD. My blood pressure's doing very well right now, and——

[Laughter.]

Senator BYRD. I'm a little concerned that if I stay around for 30 minutes, I might have a substantial rise in the level. [Laughter.]

The CHAIRMAN. Thank you very much, Senator Byrd.

Senator BYRD. Thank you, Mr. Chairman.

The CHAIRMAN. Next, we will hear from our distinguished colleague from Maine, Senator Mitchell.

STATEMENT OF HON. GEORGE J. MITCHELL, A U.S. SENATOR FROM THE STATE OF MAINE

Senator MITCHELL. Thank you, Mr. Chairman and members of the committee, and my thanks to Senator Byrd for his kind words. And I assure you, Senator, the feeling is mutual regarding——

[Laughter.]

Senator MITCHELL. In all respects.

Mr. Chairman, I come here today to urge the Members of this committee to join me and other Members of the Senate in acting to address the serious problem of acid rain.

My statement will be brief, but my message is simple and straightforward. I ask, Mr. Chairman, that the full text of my statement be inserted in the record. I will not read all of it, in the interest of time.

The CHAIRMAN. Your entire statement will appear in the record.

Senator MITCHELL. We know enough to act now, and it's our responsibility to do so. When I last testified before this committee in August 1982, the Senate Environment Committee had just approved an acid rain control strategy. It required a reduction of 8 million tons of sulfur dioxide emissions over a 12-year period.

Last month, the Environment Committee reaffirmed its previous action. By a vote of 16 to 2, the committee once again approved an acid rain reduction strategy. It requires a reduction of 10 million tons of sulfur dioxide emissions over a 10-year period.

As a committee, we have studied this issue extensively since 1977, when we held our first oversight hearing on acid rain.

We have held 19 days of hearings, heard hundreds of witnesses express every point of view, and received thousands of pages of testimony.

We have weighed all of the available evidence and exercised our judgment. We have recommended a legislative approach to address the acid rain problem. That is our responsibility, we have discharged it.

Now, it is incumbent upon the 82 Members of the Senate who have not yet exercised their judgment to do so. It is my hope that the Members of this committee will join us in our conclusion, that based on available scientific evidence, we know enough to act now.

I assure you, you will be in good company. Consider the following statement, which is a quotation:

> We recommend that additional steps should be taken now which will result in meaningful reductions in the emissions of sulfur compounds into the atmosphere beginning with those steps which are most cost effective in reducing total deposition. The incomplete present scientific knowledge sometimes prevents the kinds of certainty which scientists would prefer, but there are many indicators which, taken collectively, lead us to our finding that the phenomena of acid deposition are real and constitute a problem for which solutions should be sought.
>
> Any current scientifically derived recommendations must be based upon an imperfect, always increasing, body of pertinent data whose quality and completeness can be expected to improve for decades. Recommendations based upon imperfect data run the risk of being in error; recommendations for inaction pending collection of all of the desirable data entail even greater risk of damage. It is in the nature of the acid deposition problem that actions have to be taken, despite incomplete knowledge. If we take the conservative point of view that we must wait until the scientific knowledge is definitive, the accumulated deposition and damaged environment may reach the point of irreversibility.

That's the end of the quotation.

Whose words are these? A panel, convened by President Reagan's Office of Science and Technology Policy in the White House, came to these conclusions in June of 1983.

And yet, the administration's position is that we do not know enough to act legislatively yet. And, of course, Senator Byrd shares that view, as you have just heard.

This conclusion is, in my judgment, in direct contradiction to the weight of evidence. Reasonable persons can, and do, of course, differ in the conclusions that they draw from the same pieces of evidence.

However, there is a problem in this area. We are dealing with a moving target. Every area of scientific uncertainty that has been raised in the past by opponents of acid rain legislation has been answered by a reputable study, only to be followed by new questions and new objections.

When will the scientific threshold for action be met? Is there, indeed, any threshold at which opponents of acid rain legislation will acknowledge that we do know enough to act?

The fact is that we know as much, if not more, about this subject than the Congress knew in 1970 about that subject when it passed the Clean Air Act.

The same is true of other environmental laws, and, indeed, laws in many other areas. And who on this committee, who in this Congress now believes that we should repeal the Clean Air Act?

A standard of certainty is being suggested for this legislation that has not been utilized in the past, and probably can never be attained in this, or any other area of human affairs.

The arguments made against action now are the same arguments, word for word, that had been made against every major environmental law that has ever been proposed or considered by this Congress.

The evidence demonstrates clearly it is well established and well documented that acid rain has caused, and is causing damage to aquatic resources.

Observations in Europe and the United States now suggest that acid rain may be reducing forest growth.

Mr. Chairman, I have a long series of statements and material to be submitted for the record, and I would like to just identify them briefly.

A New York Times article which recently detailed the decline in forest growths in the Eastern United States; a statement by Dr. Ellis Cowling, discussing observed forest decline in Europe and the United States; a statement by Dr. Arthur Johnson, discussing the decline in forest growth in Maine, New Hampshire, Vermont, New York, New Jersey, Virginia, Tennessee, North Carolina, South Carolina, Georgia, and Alabama; a statement by Drs. Richard Kline and Hubert Vogelman, discussing the decline of a number of tree species in Vermont; a statement by the Board of Directors of the Tennessee Valley Authority, discussing the 56-percent reduction TVA has implemented over 6 years, and their ability to reduce by another 50 percent their sulfur dioxide emissions with the resulting utility rate increase up from 2.5 percent to 4.2 percent; a recent Sports Illustrated article, documenting the decline of the striped bass in acidic waters in the State of Maryland; a letter to President Reagan from 24 Members of Congress, including 15 Senators, 6 of whom are members of this committee, urging action on acid rain now; and two recent articles from the Louisville Courier Journal, discussing observed forest and crop damage in Kentucky which may be attributable to acid rain and other air pollutants.[1]

Mr. Chairman, it is significant that the letter to the President, which you are very much aware of, since I believe you signed it, states that these 24 Members of Congress from the Western part of the United States, including 15 Senators to the President, quote:

> We are writing to express our concerns about the problem of acid rain. As Westerners concerned with the protection of our natural heritage, we share the concerns of the northeast, and are disturbed by the environmental damage being caused by acid precipitation. We do not agree that such damage to the environment is acceptable, even though there may be no direct adverse impact on human health. We believe the time has come to develop a sound federal policy for the control of acid rain, and we intend to work with others to develop such policy.

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[1] See appendix B.

The letter goes on to criticize two aspects of the current debate. The first is the nationwide tax, and the mandatory scrubber proposals. Both, I might add, are not included in my legislation, and the letter may be taken as a strong endorsement of the legislation which I have proposed and which was approved by the Environment Committee, since it contains neither of those proposals and is consistent with the provisions of that legislation.

[The letter follows:]

United States Senate
WASHINGTON, D.C. 20510

November 17, 1983

The President
The White House
Washington, D.C. 20500

Dear Mr. President:

We are writing to express our concerns about the problem of acid rain.

As Westerners concerned with protection of our natural heritage, we share the concerns of the Northeast and are disturbed by the environmental damage being caused by acid precipitation. We do not agree that such damage to the environment is acceptable even though there may be no direct, adverse impact on human health. We believe the time has come to develop a sound federal policy for the control of acid rain, and we intend to work with others to develop such a policy.

At the same time, some of the current proposals for controlling acid rain, and financing such controls, are clearly bad policy. They are bad policy both taken alone and in light of the very unfortunate precedents they would set. We refer particularly to the "nationwide tax" and "mandatory scrubber" proposals.

A fundamental principle for dealing with environmental problems is that those who cause a problem should be required to pay for its cleanup. This principle assures that the true costs of combatting pollution are allocated fairly to the responsible parties and their consumers. Clearly, it is wholly violated by proposals for a "nationwide tax" to finance the control of acid precipitation. The Western states have already invested heavily in air pollution controls for power generation. Current SO2 emissions in the West represent only 3 percent of national SO2 emissions while the West produces 19 percent of the country's coal fired generated electricity. Since the problem is not evidenced to the same extent in the West, a "nationwide tax" would violate principles of fairness and efficiency by dictating that we in the West be required to pay to clean up a problem attributable largely to utilities outside our region.

Second, we see no reason to extend the shortsighted federal requirement that sulfur emissions be reduced using only expensive "scrubbers," even though in many instances necessary reductions in emissions may be achieved through more cost-effective alternatives. If the goal is to reduce sulfur emissions, utilities should be allowed to choose the most efficient method of reducing such emissions -- on a case-by-case basis. We see no reason why consumers should be forced to pay billions of dollars for unnecessary "scrubbers" to achieve equivalent environmental benefits. The nation's ability to invest in the environment is too limited to mandate such obvious waste.

We encourage you to press forward with efforts to identify a sound, farsighted strategy for dealing with acid rain. In our view, the approach chosen to this problem will set major precedents for dealing with future environmental risks. Serious efforts should be made to choose a strategy that is economically efficient and environmentally sound, and which therefore avoids panaceas such as a "nationwide tax" and "mandatory scrubbers." We ask that you not delay in leading the country to an equitable and cost-effective solution to the problem of acid precipitation.

Sincerely,

Malcolm Wallop
Malcolm Wallop
United States Senator

Max Baucus
Max Baucus
United States Senator

Pete V. Domenici
Pete V. Domenici
United States Senator

Alan K. Simpson
Alan K. Simpson
United States Senator

William L. Armstrong
United States Senator

Dick Cheney
Member of Congress

Ray Kogovsek
Ray Kogovsek
Member of Congress

Jim McClure
James A. McClure
United States Senator

John Melcher
John Melcher
United States Senator

Jim Abdnor
James Abdnor
United States Senator

Edward Zorinsky
United States Senator

Chic Hecht
United States Senator

Steve Symms

Steven D. Symms
United States Senator

Jake Garn
United States Senator

John McCain
Member of Congress

Dan Schaefer

Dan Schaefer
Member of Congress

Mark O. Hatfield
United States Senator

Orrin Hatch

Orrin G. Hatch
United States Senator

Larry Pressler

Larry Pressler
United States Senator

Ron Marlenee
Member of Congress

Charles Pashayan, Jr.
Member of Congress

Dan Marriott
Member of Congress

Howard C. Nielson
Member of Congress

Pat Schroeder

Patricia Schroeder
Member of Congress

Senator MITCHELL. I would also like to include a report by the National Wildlife Refuge which recently talks about the acid rain impacts in 21 States outside of New England. [Retained in committee files.]

I emphasize, these are just a very, very few in number of the many articles. These are not all scientific in nature. There are, of course, as you know, many extensive scientific studies.

But notwithstanding the substantial body of information that now exists, I support wholeheartedly continued acid rain research.

There are gaps in our knowledge. We can, and we should always learn more. But it is time to put aside our differences and focus on our areas of agreement.

We are national legislators with a responsibility to act in the national interest, and we have a serious national problem.

The first step toward a solution is to acknowledge that a problem exists. I ask you today to make a balanced judgment, based on the consensus in the scientific community, both in this country and throughout the world, that acid rain is, indeed, a serious problem which warrants a response.

We can then focus on our disagreements as to a solution. I have suggested one solution. I do not argue that it is perfect. Some of you here today have raised strong objections to my legislation. That is, of course, your prerogative, and I welcome your suggestions. I earnestly and sincerely seek a dialog with any and all members of this committee and the Senate on how best to accomplish the goal of minimizing acid deposition.

It is my belief that a legislative body that can arrive at an agreement on an issue such as Social Security, as we did last year, can reconcile our differences on acid rain legislation.

We share an overriding common interest—preservation of our natural heritage—and I might add, Mr. Chairman, our national heritage.

The waters of New England, and the forests of the Southeastern United States belong not just to people of those States, they belong to all Americans, just as the redwood forests of California do not belong just to the people of California, or the Grand Canyon belong just to the people of Arizona.

We do have a priceless natural resource heritage in this country. I believe we should preserve it. And I'm confident that if we can begin that dialog, we will find that we can arrive at an acceptable solution which is in the best interest of all Americans.

I thank you very much, Mr. Chairman, for permitting me to testify here today, and for your committee's attention. I'll be glad now to try to answer any questions anyone may have.

[The prepared statement of Senator Mitchell follows:]

STATEMENT OF SENATOR GEORGE J. MITCHELL
BEFORE THE
SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
APRIL 30, 1984

Good morning, Mr. Chairman and Members of the Committee.

I come here today to urge you to join me, and several other Members of the Senate, in acting to address the problem of acid rain. My statement will be brief, for my message is simple and straightforward.

We know enough to act now, and it is our responsibility to do so.

When I last testified before this Committee in August, 1982, the Senate Environment Committee had just approved an acid rain control strategy. It required a reduction of eight million tons of sulfur dioxide emissions over a twelve year period.

Last month, the Environment Committee reaffirmed its previous action. We once again approved an acid rain reduction strategy. It requires a reduction of ten million tons of sulfur dioxide emissions over a ten year period.

As a Committee, we have studied this issue extensively since 1977, when we held our first oversight hearing on acid rain. We have held 19 days of hearings, heard hundreds of witnesses and received thousands of pages of testimony.

We have weighed all of the available evidence and exercised our judgment. We have recommended a legislative approach to address the acid rain problem. This is our responsibility. We have discharged it. Now it is incumbent upon the eighty-two members of the Senate who have not yet exercised their judgment to do so.

It is my hope that the Members of this Committee will conclude that based on available scientific evidence, we know enough to act now.

I assure you that you will be in good company. Consider the following statements:

> "...We recommend that additional steps should be taken now which will result in meaningful reductions in the emissions of sulfur compounds into the atmosphere beginning with those steps which are most cost effective in reducing total deposition.
>
> "...The incomplete present scientific knowledge sometimes prevents the kinds of certainty which scientists would prefer, but there are many indicators which, taken collectively, lead us to our finding that the phenomena of acid deposition are real and constitute a problem for which solutions should be sought.
>
> "...Any current scientifically-derived recommendations must be based upon an imperfect, always increasing, body of pertinent data whose quality and completeness can be expected to improve for decades. Recommendations based upon imperfect data run the risk of being in error; recommendations for inaction pending collection of all of the desirable data entail even greater risk of damage.

"...It is in the nature of the acid deposition problem, that actions have to be taken despite incomplete knowledge.

"...If we take the conservative point of view that we must wait until the scientific knowledge is definitive, the accumulated deposition and damaged environment may reach the point of "irreversibility.'"

Who said this? A panel convened by President Reagan's Office of Science and Technology Policy in the White House came to these conclusions in June, 1983.

Consider the following statements:

"...Based on my study of this problem over the last few months, I would summarize what we know about acid rain at this time by the following major points:

- The northeastern United States and southeastern Canada receive rainfall that is, on average, more acidic than rainfall elsewhere in the country. Rainfall in much of the Northeast has a pH of 4.2 compared with rainfall with a pH of approximately 5.0 to 5.6 elsewhere.

- This same region is located downwind from the area in the U.S. and Canada which has the greatest density of sulfur oxide emissions.

- There are acidified, clear lakes (otherwise unaffected by man's activities) in areas which receive heavy acid deposition. In contrast, there are few, if any, affected lakes where acid deposition is less.

- Most scientists active in the field believe that acidic deposition has been a major contributor to acidification of these lakes.

- Not all areas in the eastern United States are sensitive to acid deposition. The areas at risk are those which both receive high levels of acidic deposition and have limited alkalinity or buffering capacity.

- We are seeing damage to some tree species in parts of the United States. Several environmental stresses, including acid rain, ozone, trace metals, and drought, may be interacting or acting alone to cause these effects."

Who said this? William Ruckelshaus, Administrator of the Environmental Protection Agency made these statements to the Environment Committee on February 2, 1984.

And yet, the Administration's position is that we do not know enough to act legislatively yet. This conclusion seems to be in direct contradiction to the weight of the evidence. Reasonable persons can, of course, differ in the conclusions they draw from the same pieces of evidence.

However, that is the problem--we seem to be dealing with a moving target. Every area of scientific uncertainty that has been raised in the past by opponents of acid rain legislation has been answered by a reputable study, only to be followed by new questions and new objections. When will the scientific threshold for action be met? Is thera in fact any threshold at which opponents of acid rain legislation will acknowledge that we do in fact know enough to act?

I doubt it, if the following are not adequate: two reports of the National Academy of Sciences, a report by the Office of Technology Assessment of the U.S. Congress, and the proceedings of the 1982 Stockholm Conference on acidification of the Environment.

It is well-established that acid rain has caused damage to aquatic resources.

Observation in Europe and the United States now suggest that acid rain may be reducing forest growth.

I would like to submit for the record statements by Dr. Arthur Johnson, Dr. Ellis Cowling and the West German Ministry of the Interior documenting the forest dieback that is occurring.

I would also like to submit for the record a report by the National Wildlife Federation which catalogues acid rain impacts in twenty-one States outside of New England.

Notwithstanding the substantial body of scientific information we have in hand, I support wholeheartedly continued acid rain research. There are gaps in our knowledge. We can and should always learn more. But it is time to put aside our differences, and focus on areas of agreement. We are national legislators with a responsibility to act in the national interest.

We have a serious national problem. The first step toward a solution is to acknowledge that the problem exists.

I ask you today to make a balancing judgment, based on the consensus in the world scientific community, that acid rain is indeed a problem which warrants a response.

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We can then focus on our disagreements as to a solution. I have suggested a solution. It may not be perfect, and some of you here today have raised objections to my legislation. This is your prerogative, and I welcome your suggestions. I earnestly seek a dialogue with any and all members of this Committee and the Senate on how to best accomplish the goal of minimizing acid deposition.

It is my belief that a legislative body that can arrive at agreement on such issues as social security, can reconcile its differences on acid rain legislation.

We share an overriding common interest--preservation of our natural heritage--and I am confident that if a dialogue can be started, we will find that we can arrive at an acceptable solution which is in the best interest of all Americans.

The CHAIRMAN. Thank you, Senator Mitchell.

The documents to which you make reference will be received for the record or the file, according to the nature of the documents.[1]

Senator Johnston, do you have any questions?

Senator JOHNSTON. Yes.

Senator Mitchell, a couple of years ago we passed an oil backout bill. That bill was designed to take the worst offenders that were burning coal and reduce their emissions.

We would pick specific plants and name them in the legislation for the purpose of assessing costs.

Now, again considering that you're talking about the expenditure of either tax dollars, or dollars spent by utilities, I am wondering if that is not a more efficient way than to simply go across the State and pick offenders which may or may not be contributing as much to the problem as some specific utilities are. I also wonder whether or not we shouldn't use some tax dollars. Would you comment on that?

Senator MITCHELL. I will, Senator Johnston.

First, let me say that the approach I have suggested is consistent with the Clean Air Act, since this is an amendment to the Clean Air Act, and it provides for a maximum authority at the State level.

In my legislation, an overall reduction is mandated, but then it is up to each State, working with the utility companies within that State, to identify the most cost-efficient method of achieving a reduction within that State. Governors can, of course, work together throughout regions.

That seems to me to be an approach preferable to the national government directing utilities in various States as to what may be the best approach.

Senator JOHNSTON. Well, why is that better?

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[1] See appendix B.

Senator MITCHELL. Because I think it permits those who know most about the problem, that is people at the State level and the local utility companies, to select the most cost-efficient method of achieving the results.

Senator JOHNSTON. Well, don't administrators such as Mr. Ruckleshaus and other specialists in the Federal Government know more about this problem than people at the State level who have more limited access to the scientific information?

Senator MITCHELL. I believe they do have access to scientific information, and I certainly mean no denigration to Mr. Ruckleshaus, for whom he knows I have a very high regard, he's an extremely knowledgeable official, but it's my guess that—it is my hope, I would say, not my guess, that he will agree that, to the extent possible—and that's the whole framework of the Clean Air Act—that we ought to permit those at the local level, the State level, the maximum flexibility in achieving any reduction.

With respect to the second question of Federal contribution, that may be necessary. Until now, our legislation has been based upon the principle expressed, I think as well as could be expressed, by the letter that Senator McClure and other members of this committee sent to the President, who said, quote, "A fundamental principle for dealing with environmental problems is that those who cause a problem should be required to pay for its cleanup," close quotation. That is the principle upon which my legislation is based.

I welcome any suggestions as to alternative methods, if the burden of applying that principle in this specific instance becomes intolerable, particularly upon States which are already suffering economically.

That, I think, is one of the serious problems which we confront, and which we must resolve. And I hope we can do that. And I'm certainly open to suggestions. But the difficulty is that the States that are the hardest hit economically now will be asked to sustain the burden, even though their electricity rates are already far, far below those in other parts of the country, and will continue to be far below those in other parts of the country even if my bill were enacted tomorrow and implemented right away.

Nonetheless, we have to recognize their difficult situation and attempt to accommodate that, and I hope we can do that, Senator, and I certainly would welcome any suggestions you have in that regard.

Senator JOHNSTON. One final question.

Is the weight of evidence, in your view, that acid rain deposition is increasing, or is it remaining at a constant level?

Senator MITCHELL. It is level—and I might take this occasion to comment on Senator Byrd's remarks in that respect.

I have before me excerpts from an acid rain briefing document prepared for Mr. Ruckelshaus by the EPA's Acid Deposition Task Force, dated August 1, 1983. It addressed precisely that question.

And it said, and I quote, "There is considerable uncertainty about future SO and NO_x emission trends. Assuming no change in current regulations, the current level and distribution of SO_2 emissions are not expected to shift dramatically in the future. Over the next 20 years, SO_2 emissions are projected to remain roughly constant. With emissions from the utility sector declining in later years, SO_2 emissions from the industrial sector are expected to increase."

That much was correct. However, there was no basis in this report at least for the conclusion stated by the Senator that thereafter there will be a decline in overall SO_2 emissions.

The EPA concluded that that information was not available, and declined to make an estimate as to the level of emissions after the year 2000. The table in this simply says the information is not available.

Senator JOHNSTON. Well, is the main purpose of your bill to reverse damage that's going on now, or to keep the damage from getting worse?

Senator MITCHELL. To prevent further damage which may well be irreversible. It is a cumulative effect. And notwithstanding the fact that it is true that sulfur dioxide emissions are not going to increase, the crucial question is, at the current level of emissions damage is occurring that is severe and may be irreversible.

Senator JOHNSTON. Thank you.

Thank you, Mr. Chairman.

The CHAIRMAN. Senator Evans.

Senator EVANS. No questions.

The CHAIRMAN. Senator Ford.

Senator FORD. Thank you, Mr. Chairman.

I only have one question, and maybe, too, an observation to make.

I'm very pleased with my colleague's interest in this legislation. It's broadened his newspaper reading ability to the great State of Kentucky. And I'm sure he's only filed those statements that fit his position. Therefore, Mr. Chairman, I ask unanimous consent that I might file the other positions—one which was written last week—to the hearing.

The CHAIRMAN. Those statements will be received for the record.

Senator FORD. Thank you.

Mr. Chairman, also, the reference has been made to TVA in Senator Mitchell's statement. It's very easy for them to comply when they're closing down coal plants and going to nuclear, and they've overbuilt on nuclear and had to mothball those. So it will not be a tremendous problem for TVA.

It will be a tremendous problem for my State, with the estimate of $700 million annual cost to the ratepayers and a loss of approximately 60,000 jobs if his bill goes into effect.

And I hope he will not feel too unkind toward me as I try to defend my major industry and the cost to my constituency.

Senator, what would be the effect of taking 1973 as the base year and reducing the SO_2 emission level to that of the level proposed in your pending legislation?

Senator MITCHELL. I'm sorry, Senator?

Senator FORD. Take your base year instead of 1980, 1973, and reducing SO_2 emission level to that of the level proposed in your pending legislation?

Senator MITCHELL. I do not know, Senator, from memory what the level of emissions was in this country in 1973. So I'm not able to answer the question. But I'll be happy to submit an answer to you.

Senator FORD. That was the highest.

And what you have to take into consideration is that a 500 thousand tons annual reduction in my State was completed basically between 1973 and 1980; and, therefore, my State has already spent a great deal of money, in the billions of dollars, to bring our operation into compliance. And this legislation, even if it passes under these circumstances, we lose the ability to take the credit for the reduction between 1973 and 1980.

And it seems to me that while we're talking about 1980, if it was 1981 or 1982, the economy would have reduced the emissions, and when it starts back up, then you're putting a harming effect as it relates to those industries that might use coal.

Senator MITCHELL. Senator, that is a problem that exists in other States as well. Several western Governors testified before the Environment Committee along a similar vein. I invited them—and I extend the invitation to you—to submit specific proposals to deal with that, some form of credit for past reductions over some period of time.

I certainly would be very much interested in working with you to try to develop something like that.

Senator FORD. Well, Senator, I intend to have that kind of an amendment, if the bill ever comes to the floor for consideration.

Senator MITCHELL. That's fine.

Senator FORD. Thank you, Mr. Chairman.

The CHAIRMAN. Senator Mitchell, I have just a couple of brief points.

You have indicated in your legislation that you believe the States ought to have primacy with respect to the ways in which they will deal with the problem under a mandated umbrella. Is that correct?

Senator MITCHELL. That's correct, Senator.

The CHAIRMAN. Do you have any concerns that States might look at the job impact within their States and be in favor of actions that would increase jobs and leave it to other States to meet the overall goal?

Senator MITCHELL. Yes, indeed, Senator. And the bill then provides that upon the failure of a State Governor to submit to the EPA a plan for approval within 24 months afterward, there is a fall-back cleanup strategy that will be implemented by the EPA.

The CHAIRMAN. What is your feeling about the current State implemention plans that are already under the Clean Air Act and adopted and approved by EPA?

Senator MITCHELL. The reason that this legislation is necessary, of course, is that State implementation plans, by definition, only affect both emissions and effects within a State.

The concept was initiated at a time when the phenomenon of acid rain was not widely perceived or understood, and did not, in fact, take into account the effect of transboundary pollution.

Indeed, it may be argued that the current State implementation plan encourages the export of pollution.

As you know, Senator, following the passage of the Clean Air Act originally, before they were outlawed, many dealt with the problem by simply building tall stacks which, by emitting the pollution into the atmosphere at a point high enough above the ground to assure that it would not fall to the ground within the vicinity of the emitting facility. And if you build it high enough, of course, why it would get into the next State or, as we now know, the next country.

And so it is that State focus under the—that requires, indeed, creates the demand for legislation of this type.

The CHAIRMAN. You made several references to a letter which I and other Senators signed, particularly from the Western part of the United States, and you characterized it as an endorsement of your legislation.

Senator MITCHELL. No.

The CHAIRMAN. You characterize it however you like, but I assure you it's not intended for that purpose.

Senator MITCHELL. No, I understand that, Senator. I think I said that I believed it may fairly be interpreted as an endorsement of my legislation.

The CHAIRMAN. I understand what you said, that's why I thought it was necessary that I say what I said.

Senator MITCHELL. Right. [Laughter.]

Well I must say, Senator, I thought it was an excellent letter. [Laughter.]

The CHAIRMAN. I thank you.

One of the concerns that many of us have is not only the status of the technical knowledge and, the data base, but whether or not we can, with any reasonable assurance, know that actions produce results.

My understanding of what you're saying is, you're satisfied that actions will produce results roughly in parity to the actions.

Senator MITCHELL. Yes, Senator.

The CHAIRMAN. If I say that incorrectly, I hope you will correct me.

Senator MITCHELL. The second National Academy of Science's study addressed that very question, because that was one of the principal objections raised by opponents to legislation when I first introduced my bill in 1981. The argument and opposition then was there can be no assurance that deposition will occur in proportion to reduction in emissions. The scientific term is whether or not there is linearity between reduction in emissions and deposition reduction.

And the National Academy of Sciences concluded that on a regional basis, given proportionate reductions, that there is indeed linearity as between reductions in emissions and reductions in depositions.

And I believe that. I accept that, Senator, as an accurate assessment.

The CHAIRMAN. What is the region to which the report made reference?

Senator MITCHELL. Generally the eastern region of the United States.

The CHAIRMAN. So it's the eastern region of the United States, and not a local subregion. And we should understand it in the context of the entire Eastern United States.

Senator MITCHELL. That's correct.

The CHAIRMAN. As I read S. 768, it would require unequal reductions among the States. New York would reduce its emissions by 26 percent, while Georgia which has comparable levels of emissions, would have to reduce its emissions by 73 percent.

Senator MITCHELL. The amount of emission reduction in each State is based upon the extent to which emissions in each State exceeds the current standard for known facilities of 1.2 pounds of sulfur dioxide emissions per million British thermal units of energy produced.

The CHAIRMAN. I would note, however, that 11 States, Florida, Georgia, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, Missouri, Tennessee, West Virginia, and Wisconsin, would absorb 79 percent of the reduction requirement, and they have emitted 9 percent of all emissions from the 31 States in the bill. New England and New York would bear less than 5 percent of reductions. Is that correct?

Senator MITCHELL. I don't believe so, Senator, but I don't know the document from which you're reading, and I would have to check that. I frankly doubt that the 11 States you have identified emit only 9 percent of the total amount of emissions within the region.

The CHAIRMAN. Well, I would welcome any further statements you might have on that, if you would like to look at that, and then reply for the record.

Senator MITCHELL. I'd be very happy to, Senator, if your staff would provide us with a copy from the document which you're reading and providing the method of computation. I'd be very happy to do that.

The CHAIRMAN. Sure.

Senator FORD. I think what the chairman is saying is that Kentucky and New York emit about the same, and New York would have only about 5 percent, and we would be carrying the major load.

There is a local source problem which has not been addressed here and——

Senator MITCHELL. That's right.

Senator FORD [continuing]. The equity and fairness of the legislation begin to rub a little bit.

Senator MITCHELL. Well, I understand that's a problem, Senator, determining where the emissions are to be made. And, again, I welcome any suggestions you or any member of the committee may have for a more equitable method of effecting such an emission.

Senator FORD. And, Mr. Chairman, the distinguished witness said something about linear problems. Let me just read here: A principal conclusion of the NRC Committee regarding the relationship between emissions and sulfur dioxide and deposition.

The Chairman of the NRC states in his forwarding letter that it is, quote:

> The committee's judgment that if the emissions of sulfur dioxide from all sources in this region, northeastern North America, were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition. The National Laboratory Consortium Reviewers disagree almost uniformly with the methods used to reach this conclusion and with the conclusion itself.

Senator MITCHELL. I thank the Senator for that comment. I would submit for the committee's consideration the testimony taken at a full day of hearings before the Environment Committee on the conclusions of the National Consortium of Reviewers. I believe that any member of the committee who looks at the National Academy of Science's report, the thorough peer review process through which that report went and then the—and I'm trying to choose my words carefully—what I would call the hasty conclusions of the National Consortium, not subject to peer review, would conclude, I believe that the National Academy of Science's report can stand on its own.

The National Academy of Science doesn't need me to defend it, I'll say that. I think that National Consortium of Reviewers does need someone to defend it.

Senator **Ford**. Well, let me just say, Mr. Chairman, I think that will be defended later on in the day. So we're going to have a full day of hearing on this, too.

The **Chairman**. Senator Mitchell, thank you.

I would just like to add for the record that at this point the statement of the National Acid Precipitation Assessment Program letter, dated February 22, 1984, addressed to Representative John Dingell, in which they cast some question on the issue of linearity; that's a matter that troubles a great many people, I think.

[The letter follows:]

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM
722 JACKSON PLACE, N.W.
WASHINGTON, D.C. 20506
202/395-5773

February 22, 1984

Representative John D. Dingell
Committee on Energy and Commerce
2221 Rayburn House Office Bldg.
U.S. House of Representatives
Washington, DC 20515

Dear Representative Dingell,

In your letter of October 25, 1983 you requested that I try to clarify the apparent conflict between the National Academy of Sciences' (NAS) most recent report on acid rain ("Acid Deposition: Atmospheric Processes in Eastern North America") and the National Laboratory Consortium (NLC) critique of that report. I discussed my response in November with Dr. Dugan of the Science and Technology Committee and Mr. Finnegan of the Committee on Energy and Commerce. With their agreement, I have attempted to develop a statement defining the nature of the controversy. The statement was subsequently circulated to Dr. Calvert (chairman of the NAS committee) and Dr. Manowitz (leader of the National Laboratory Consortium) for comments and revision.

The enclosed statement has been accepted by both parties as being a reasonable and accurate description of the situation. I apologize for the long delay in completing my response to your request, but the review process took time. The resulting statement is more valuable because it represents a consensus.

The differences between the NAS report and the NLC critique result more from variations in approach and perspective than substance. With the limited data currently available, emissions and deposition appear to be behaving nearly linearly (i.e., proportionately 1:1) when averaged over at least a year and averaged spatially over a large half-continent sized area. This is a valid hypothesis based on current information which will be tested as new research yields better information. However, both parties agree that for smaller spatial scales and shorter time scales the relationship may not be directly proportional.

For example, a 50 percent reduction in sulfur dioxide emissions throughout the eastern half of the United States may lead to an overall average reduction of 50 percent in deposition, but the change in deposition will vary from place to place and from time to time in ways not yet predictable. In other words, linearity may apply to the average deposition and yet not hold true for each receptor site of concern.

Both the Academy Report and the NLC critique emphasize the pressing need for additional research. The National Program is implementing many of the specific research recommendations that have been made by the reports. The vigorous research effort in the National Program is addressing the uncertainties and progressingly will narrow them in coming years.

I hope this attempt to clarify the state of the science is helpful. Please let me know if I can be of further assistance.

Sincerely,

Chris Bernabo

Chris Bernabo
Executive Director

cc: Jack Calvert, NAS
Bernie Manowitz, NLC
Bernard Goldstein, EPA
Courtney Riordan, EPA
Lester Machta, NOAA
Orville Bentley, USDA

Statement enclosed

Relationship Between the Calvert Committee (NAS) Report "Acid Deposition: Atmospheric Processes in Eastern North America" and the National Laboratories' Critique

The criticisms of the recent NAS report expressed by the group of scientists at national laboratories appear to be more a matter of emphasis than of fundamental differences in sources of data or in interpretation.

Both the national laboratory critique and the NAS report agree that in general the detailed processes involved in acid deposition are inherently non-linear. The NAS committee expressly set out to determine the extent of the non-linearities. It found that sufficient data for the analysis were available only for assessing relationships between long-term (annual) average values of emissions and deposition integrated over large spatial scales. Several lines of evidence and theoretical calculations suggest that if non-linearities exist between annual average emissions and deposition over large areas, they are not dominant. The NAS report phrased its conclusion as "there is no strong evidence that the relationship is non-linear" because the data are not sufficient to prove the relationship is linear. The data can only be used to assess the strength of the non-linearity.

The NAS report points out that short-term events (episodes) are very complex and may indeed involve non-linearities. Non-linearities clearly arise, for example, in short-term meteorology and may be important for chemical processes taking place in clouds in winter. When the individual episodes are summed or averaged over the year, however, the non-linearities appear to balance out, or in the case of cloud processes in winter, apparently do not contribute much to annual totals.

Both the NAS report and the national laboratory scientists agree that further research on atmospheric processes is crucial to advancing our knowledge of the phenomenon of acid deposition. If we are to improve our ability to construct computer-based models useful for predicting the consequences of alternative emission control strategies, we need to study the detailed processes that occur on short temporal and spatial scales, where non-linearities can be expected. Only by building up this area of understanding can we have confidence that the models accurately reflect what is happening in nature and that reliable projection of the specific consequences of targeted emission reductions can be made.

The NAS report asserts that current models are not sufficiently tested to be relied upon for quantitative evaluations of the consequences of targeted control strategies. This conclusion is, of course, a matter of judgment.
Dr. Calvert, chairman of the NAS committee, has suggested in congressional testimony that current models can make, and have been used to make broad-based qualitative comparisons that have provided useful contributions to the policy debate.

The seeming conflict between the NAS committee report and the comments of the National Laboratory Consortium's scientists is therefore more apparent than real, resting mainly on different approaches.

This statement was reviewed by Dr. Calvert (NAS) and Dr. Manowitz (NLC) and is agreed to represent an accurate and reasonable description of the situation.

Senator MITCHELL. Thank you, Mr. Chairman. I'm not familiar with either the organization or the letter, but I would ask that I be provided a copy, and if I have any additional comments, I'll be glad to submit them.

Thank you, Mr. Chairman.

Senator EVANS. Mr. Chairman.

The **CHAIRMAN.** Senator Evans.

Senator EVANS. Senator Mitchell, I've been listening both in the Committee on Environment and on this committee and have read considerably on this issue. It seems to me somewhat ironic that some are questioning indeed the very correlation between acid rain and deposition, the question as to whether it's detrimental even. And yet, do I understand correctly, that the techniques of the past have generally been to build very high smokestacks for some reason, and I'm curious if you would enlighten me as to why the smokestacks were built so high?

Senator FORD. EPA mandated them.

Senator EVANS. Long before EPA was invented.

Senator MITCHELL. I believe, Senator, that the reason obviously, at least to me, and there are others much more knowledgeable in the field than I, was because under the Clean Air Act, the air quality was measured at ground level. And if you are emitting a substantial quantity of any form of pollution that may be subject to movement within the atmosphere, the higher above-ground at which you emit it, the less likely it is to be measurable at the location of the facility at which the smokestack is located.

And I think the intent of that is fairly obvious. And of course, that was an unanticipated problem which was corrected in later amendments to the Clean Air Act.

Senator EVANS. I wonder if a possible immediate correction might be to require that no smokestack be built more than 30 feet high and let it fall in on the localities, and if they like it, it doesn't affect you.

Senator MITCHELL. I think that is an alternative, but I would point out—and I know that the Senator is serious—that acid deposition in the East is primarily composed of sulfur dioxide, but there is also a nitrogen oxide component.

Senator EVANS. I'm aware of it.

Senator MITCHELL. In the West, the proportions are reversed, as you know, and nitrogen oxide is emitted through a lot of small automobiles and other facilities that don't lend themselves to this kind of regulation. And even though they emit very close to the Earth, in fact, they still do to some extent get up in the atmosphere.

So I think the most reasonable approach is the one that I have suggested. But, again, I welcome any suggestions by members of this or any other committee.

Senator EVANS. I suspect that your approach is a little more practical.

Senator MITCHELL. Right.

The **CHAIRMAN.** Thank you very much.

Senator MITCHELL. Thank you, Senator.

The CHAIRMAN. We will receive for the record at this point a statement for the record by the Honorable Dan Quayle, Senator from Indiana.

[The prepared statement of Senator Quayle follows:)

TESTIMONY OF
SENATOR DAN QUAYLE
BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
APRIL 30, 1984

Mr. Chairman, Members of the Committee:

I am very pleased that this Committee has once again convened to receive testimony regarding the interaction between the acid rain issue and our nation's energy policies. The Committee's hearing held two years ago this summer provided a wealth of information on this subject and I have every reason to believe that such will be the case today.

I regret that I am unable to deliver my testimony personally before the Committee. Today, I am touring the coal fields of Southwestern Indiana and I am taking a quick side trip to neighboring Kentucky to see first hand the demonstration of atmospheric fluidized bed combustion at Paducah.

I believe that strategies to control sulfur dioxide emissions as a solution to the acid rain problem, such as those now under discussion in Congress, are premature and cannot guarantee to solve the problem. I believe that President Reagan heeded the voices of wisdom and reason in proposing a program of more research, mitigation, and development of new technology. Let me outline my reasoning in a bit more detail.

First, the scientific evidence does not justify stringent controls on the Midwest. Sulfur dioxide emissions have been declining in recent years. Nationwide, sulfur dioxide emissions would be 50%

greater in 1980 than they actually were had efforts to reduce pollution not been made. In Indiana, the average sulfur dioxide emission rate for each million Btu's used for electricity generation has declined by 11% between 1973 and 1980. This does not include credit for sulfur dioxide reductions from flue gas desulfurization systems.

During this same time frame, the U.S. Geological Survey found very little change in the acidity of bulk precipitation. Data from the Hubbard Brook Ecosystem study, conducted from 1963 to 1977, indicate a decrease in sulfate concentrations, and an increase in nitrate concentrations in rainfall, but did not indicate any trend in pH. While the national Academy of Sciences reported a relationship between emissions and deposition in the eastern North American continent, they could not determine the "consequences of emission reductions in a smaller region, such as the Midwest, for deposition in another region, such as the Adirondacks or southern Ontario."

Second, emission reductions of the magnitude proposed can only be achieved at onerously high prices. A least cost estimate for the proposed controls in the thirty-one affected states is set at $3 to $4.5 billion annually. On average, utility rates in the region would increase 10% to 15%. But, for those utility systems which rely on high sulfur coal, the rate increase would be steeper.

Third, the control strategies now being discussed would place a disproportionate burden of the clean-up requirements on the Midwest, resulting in enormous burdens for Indiana and its citizens. My State was one of the hardest hit in the most recent recession. To impose stringent controls now would jeopardize our current economic upturn.

Additionally, the control strategies are not equitable on a nationwide basis. Under one proposal, which mandates a 10-million-ton reduction over 10 years, eight midwestern states would be required to cut emissions by an average of 58%. The New England states would have to reduce emissions by an average of only 12%.

Consider the devastating consequences of an 8-million-ton reduction scheme on the State of Indiana:

--The capital costs to build and retrofit existing electric generation facilities would be an estimated $1.85 billion.

--Indiana's coal industry would be crippled. Absent any new controls on the burning of high-sulfur coal of the type mined in my State, Hoosier coal production could be expected to rise from its 1980 level of 31 million tons to 46 million tons in 1995. But, Indiana's 1995 coal production would be cut in half, or only 22 million tons -- almost one-third less than the 1980 production level -- under an 8-million ton strategy.

--According to a study by the Congressional Research Service, between 1,500 and 1,800 direct jobs would be lost from acid rain legislation. Total employment loss would be between 4,900 and 5,850 in the four-county area of Indiana that produces 70% of Indiana's coal destined for electric utilities.

--Coal industry revenues in my State would be reduced by $476 million. The direct and indirect costs of increased unemployment would be a loss of over $64 million in revenues to the State and local governments.

Given these burdens on my State alone, the Senate Environment Committee has "magnanimously" increased the emissions reductions from eight million tons to ten million tons. A bad situation has suddenly been made worse! The legislation reported by the Environment Committee will be economic suicide for my State and the entire industrialized Midwest.

I support President Reagan's call for more research. We need more analysis of the impact of local and distant sources on sensitive areas. The National Academy of Sciences stated that "the further a source is from a given reception site, the smaller its influence."

In addition to the source-receptor -- local vs. distant pollution analysis, more study of petroleum use is needed to determine its precise influence on sensitive areas. As was brought out in the hearings conducted by this Committee two years ago, the Northeast comprises less than 5% of the area of the lower 48 States, but it burns 36% of the distillate fuel and 40% of the residual oil in the United States. Consumption of oil by Northeastern powerplants has increased by a factor of about five since 1960.

We know that the costs and burdens of these control schemes are high, but do we also know what these scientifically unfounded schemes will bring us in terms of benefits? The Hudson Institute also asked this question in their review of the acid rain issue -- "Would the present legislation, if it were to reduce sulfur oxide emissions by 50% overall, result in a 50%, 20%, 10%, 5%, or 2% reduction in acid precipitation in a supposedly sensitive region such as the Adirondacks? To that question the only clear answer that we can have confidence in today is that we don't know!" Such control strategies may not produce the desired results or anything approaching the desired results.

Mr. Chairman, I would commend the Hudson Institute's study of the acid rain issue to the Committee as a good review of the evidence and claims regarding this issue. I request that an executive summary of the Hudson Institute study, commissioned by the Hoosiers for Economic Development, be included in the Committee record of today's hearing.

I share this Committee's concern about acid rain control programs and their interaction with our energy policies. In Indiana, more than 98% of the electricity generated comes from coal-fired power plants. Coal is an abundant, domestic resource; it is not supplied by the Mideast, or other potentially unstable areas of the world. Also in Indiana, consumers are paying or soon may be forced to pay for two cancelled nuclear power plants. On top of this burden, we cannot additionally support acid rain controls. I have serious concerns that efforts to control so massively emissions over the next decade will stifle the development of technologies that will enhance our ability to utilize high-sulfur coal in a more efficient manner.

In conclusion, I heartily support the President's recommendations as outlined in his State of the Union Address. The President announced efforts to double our research efforts on the science of acid rain. This can only lead to a greater understanding of the nature of the problem to aid policymakers in development of a more equitable solution. Mitigation efforts in the affected areas will be undertaken while the additional research is being conducted. I strongly support the President's efforts to place emphasis on the development of cleaner and more efficient coal-use technologies. Indeed, this is the key to a solution to the acid rain dilemma.

Mr. Chairman, I appreciate this opportunity to share my views with the Committee.

II. EXECUTIVE SUMMARY AND OVERVIEW

Currently at least several hundred scientists around the world are involved in debates about various technical issues related to acid rain--at least the portion of it which stems from anthropogenic (man-made) sources. Here are some of the issues:

1. How much acid is produced? There is general agreement that the burning of hydrocarbon fuels (coal, oil, natural gas, wood, paper, in the U.S., etc.) creates emissions which contain about 25 million tons of sulfur oxides, 20 millions tons of nitrogen oxides, and smaller quantities of other less important acid precursors. A fraction of these will end up as acids in the atmosphere (primarily sulfuric and nitric acids) probably within a few days. How much of these emissions actually is converted into acids is not known, although it is undoubtedly a substantial fraction. Because the amount of acid formed depends upon many capricious meteorological factors (winds, clouds, temperature, humidity, rainfall, sunshine, turbulence) as well as atmospheric dust, time of day, season, and possibly many other non-meteorological factors (not all of which are even known) that amount is undoubtedly a highly variable quantity over time. Long-term averages, when they become determined over time by enough research, might show that roughly half of the emitted precursors eventually become acids--but that is only a guess, not a solid scientific fact. A few years of an adequately funded research program should provide a respectable answer to the question.

2. How much acid precipitation reaches the ground in the geographical areas which many people have claimed are relatively sensitive? Here again the answers are not precise, in part because of the extreme variability of the measured results. In a single rainstorm the acidity can vary greatly--by a factor of 4 or more--over the region receiving the precipitation. In fact, the measured acidity of rain at any single receptor can also vary by a similar factor during the course of a storm. It does not necessarily follow that the acidity is greater at the beginning than at the end of a storm, or the other way around. There are no simple answers to those questions.

Some of the acid formed in the atmosphere may reach the ground as "dry" precipitation. That usually means in other ways than through rain or snow and includes fogs, direct contact with surface features, and oxidation to acids of gaseous precursors after they are adsorbed onto various surfaces. Also, a portion of the acid formed is neutralized in the atmosphere or on the ground, and another portion is dissipated in the ocean.

Research efforts are now underway to provide better quantitative information about the amount of acid precipitation received in various regions of the U.S. but it will probably take a few years before high confidence can be placed in the accuracy and usefulness of the knowledge gained. Even then it is probable that knowledge about the amount of dry acid deposition will lag that of wet deposition--perhaps for a considerable time.

3. How much of the acid deposition in any particular area comes from sources which are local, how much from nearby emissions (e.g., within 200 miles), and how much comes from distant sources, several hundred miles distant or more? Currently this issue is especially important because the sources of sulfur oxide emissions that are obvious targets for regulatory control are the large coal-burning power plants which are relatively concentrated in the mid-western states while the areas claimed to be the most sensitive to acid rain are in the Adirondack Mountains of upstate New York and parts of southeastern Canada.

At the present time, even though the legislation now being proposed in Congress focuses on controlling SO_2 (sulfur dioxide) emissions from mid-western utilities, it is not known whether that program will make a significant change in the amount of acid deposition in the Adirondacks. Indeed, it would not be at all surprising to find that the program made only a barely noticeable change in the measured amount of acid rain in upstate New York even after 10 years and a commitment of $100 billion (in 1982 dollars).

On the other hand it may be possible, though not likely, that the same program could reduce the amount of acid precipitation in the Adirondacks by as much as 25 percent. However even with that favorable outcome would the effects of that change in deposition be noticeable? That is, would fish appear or be able to survive in some of the lakes which are now barren of them? Would some forests which now appear to be dying become revitalized? As we shall see, there is a very great uncertainty about achieving any observable results even under favorable assumptions about the change in the amount of acid deposition.

4. Do scientists now reasonably understand the effects of acid rain upon various parts of the environment? This may be the most important technical issue. That is, how bad is acid rain? What damage is it doing? Will it get worse over time?

A substantial part of this report will deal with those questions in some detail. We can summarize the answers that are now being given by scientists in the following way. The scientific community is strongly polarized at present. Many scientists tend to believe that acid rain is responsible for the loss of fish in some lakes and other undesirable aquatic effects in the more sensitive areas; that it poses threats to some kinds of forest in some regions; and that it has potential deleteriou effects on human health as well as accelerating erosion or corrosion on exposed buildings, monuments, and vehicles. However they usually concede that the evidence is circumstantial--that is, other explanations for the observed effects, while not known, cannot be ruled out.

On the other side of the damage issue we find scientists who claim that the acidity of lakes and streams even in the most sensitive areas are due to natural causes, sometimes with an assist from past land-use practices (such as logging, fire control). In particular, they assert that the acidity of lakes and streams is almost completely determined by the soil conditions of the associated watersheds and that these conditions can hardly be affected by the small amount of acidity (2-4 parts per million) that arrives in acid rain (even at 4 ppm--equivalent to a pH of 4.1--it would take 85 years to deposit an ounce of sulfuric acid on a square foot of soil). Similar rebuttals are made to the claims that acid rain is harming the forests, or agricultural crops or that its impact on human health or on erosion or corrosion of exposed material surfaces is significant in comparison with other processes.

Indeed the only major area in which a consensus exists is that reducing emissions which create aerosols would result in improved average atmospheric visibility, but even that has not been quantified. In fact, it is at least doubtful that the improved visibility would be noticed by many citizens even after the $100 billion is spent on reducing emissions.

5. In light of the available technical information, what can be done and what should be done about acid rain now, in the near future, and over the long term? That is, what might be the best policy at the federal level?

This is a very complicated issue especially in light of the extreme uncertainties in the scientific knowledge and because of what appears to be huge costs and conjectural benefits in the currently proposed legislative initiatives. As this issue is likely to remain active for years acid-rain policy probably will be reviewed frequently as policymakers attempt to respond rationally to the political pressures and to the best technical estimates of the cost-effectiveness of various mitigative measures. Our tentative recommendation to federal policymakers is as follows:

a. Expand the national acid-precipitation research effort over the next 5 years or more, up to $150 million per year, if necessary ($18.2 million dollars were spent by the federal government in 1982). It is important to get solid scientific information if the government is to formulate reasonable responses to the potential damage from acid precipitation and to avoid costly boondoggles.

b. Encourage the development of improved cost-effective technologies for reducing the emission of acid precursors and other pollutants from all sources, large and small. These technologies are likely to be needed in many new installations in any event, and would be desirable in a program which requires extensive retrofitting. In particular, new methods of removing sulfur from coal before it becomes a flue gas appear to be potentially very valuable over the long term. The federal cost of providing incentives to private industry for such a program might exceed $200 million per year over the next several years, but if properly formulated it should be an excellent long-term investment.

c. To the extent that liming of selected lakes and streams can be shown to be a desirable and cost-effective interim, if not long term, measure for creating a desirable ecological balance that approach should be pursued. A cost-sharing federal-state prototype program might be advisable over the next ten years. It is hardly likely that even a large effort involving 200 lakes would cost as much as $20 million/year in 1983 dollars.* If it is successful it could reduce one of the major current causes of political pressure to take hasty legislative action of a costly and potentially disruptive nature.

d. An experimental retrofit program involving $.5 to $1 billion/year for controlling acid-forming emissions from major sources nearest to the sensitive Adirondack area could be the first phase of a potential long-term program of retrofitting--it remains to be proven through research that a Phase-II would be desirable. The initial retrofitting would probably involve power plants and possibly other large industries in New York, Pennsylvania, New Jersey and possibly some New England states. That experimental program could be based upon the substitution of low-sulfur coal or natural gas for present high-sulfur coal or other sulfur-containing fuels. If it were based upon the use of scrubbers it would be more costly. These changes should be integrated into the acid deposition research program in a timely manner in order to test the predicted impact of those changes against the observed results.

e. The last (and still tentative) recommendation is that due consideration be given to a stronger policy of controlling the emission of acid-forming pollutants into the atmosphere from all new fuel-burning installations and vehicles. The heart of such a program would be the requirement for some stipulated level of control technology to be incorporated into each relevant change in the nation's capital stock. That is, every new engine, boiler, furnace, heater, cooking facility, etc., purchased or installed after, say, 1984 would have to meet a specified minimum performance level. As technology progresses over time that minimum level could gradually be made more stringent. In that way as the capital stock of the nation gradually rolls over, it will become increasingly effective in reducing all air pollutants, and the acid rain precursors in particular. With such an approach a great deal of progress in reducing all air pollution should occur steadily over the long term without the ugly prospect of compulsory, unfair, costly, and possibly ineffective retrofitting.

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*According to EPRI, lake-liming costs should average about $60 per acre. The 178 Adirondack lakes in critical condition have about 7,500 acres. Thus about $4.5 million would be required for each application if all of them were to be limed. Repeat applications may be required every three years or so. EPRI, EA-2362, Feasibility Study to Utilize Liming as a Technique to Mitigate Surface Water Acidification, April 1982.

* 6. What could affect public opinion and the political climate in which policy decisions will be made? Public opinion attitudes indicate that the pragmatic approach to problems, particularly domestic problems, remains the same as it has been since the 1930s. On environmental issues there is a broad-based consensus which cuts across all party lines, and includes all ethnic and regional groups. Although people remain concerned about the environment, they are currently much more concerned about economic issues and they expect a balance to be struck among efforts to preserve the environment, sustain economic growth, and create more jobs. The apparent "paradox" merely means they want prosperity without too great a cost to the environment and vice versa.

Currently the general attitude of the public, although reflecting a 20-year trend of more liberal thinking on issues of personal behavior, continues to be center or center-right politically. The public's values regarding family, community, schools, etc., remain basically the same. For example, an overwhelming majority are in the center to center-right on school busing, the death penalty, and banning hand guns.

Recent polls show that environmental considerations are near the bottom of the list of most important issues, or do not even appear on the list. Inflation, unemployment, crime and the conditions of the schools are all now more important than environmental issues. On the other hand, when asked directly, citizens will express a considerable concern for the environment and would prefer that more money be spent to protect it--even if it means higher taxes, utility bills, etc. In this context it is important to understand that probably over 100 million people use the "great outdoors" for recreation.

Specifically pertinent to the question of acid deposition, an estimated 45 million fresh water fishermen, and 12 million hunters, among others, would be disturbed if they believed that it would cause serious damage to the woods, streams or lakes--or even to the aquatic flies on which the fish feed. These people love the lakes, rivers and woods and spend considerable amounts of money to preserve them. They are "professional" environmentalists in this sense. Although basically low-profile people, they can become very active if they believe their favorite recreation is threatened. However, their activism is invariably within the traditional democratic process, and they vote often in both local and national elections.

The outdoors people are different from the relatively small group of single-issue environmental activists, who have been described as "public interest elites." These elites have been found to be atypically liberal or "cosmopolitan" in their standards. Almost 60 percent have family incomes in excess of $50,000 a year and 90 percent regard themselves as liberals. Their involvement with environmental issues leads them to give economic considerations a much lower priority.

Other groups of "activist" environmentalists, however, represent a much broader following. For example, the National Clean Air Coalition includes some organizations that have long been identified with environmental issues and others which previously have not. However, its position against acid rain is relatively extreme compared to those of the American Chemical Society or the American Association for the Advancement of Science.

Potentially, a great concentration of public opinion on legislation dealing with acid-rain might stem from a coalition of some otherwise unlikely partners. That could occur if the National Clean Air Coalition joined with some fishermen's groups and generated enough publicity to get other outdoors recreational groups involved.

This analysis does not imply that the larger coalition or a political groundswell is imminent. As fishermen and hunters now have higher-priority concerns, their votes are driven largely by critical economic issues. On the other hand, in tight political races their views on the acid rain issue could determine the outcome, if they become convinced of the need for action.

The CHAIRMAN. We would call as our next witnesses the Honorable Donald P. Hodel, Secretary, Department of Energy; the Honorable William D. Ruckelshaus, Administrator of the Environmental Protection Agency; the Honorable A. Alan Hill, Chairman of the Council on Environmental Quality.

It's my understanding that by agreement among the witnesses, Mr. Ruckelshaus has the principal statement. Is that correct? So I'll ask him to lead off.

STATEMENT OF HON. WILLIAM D. RUCKELSHAUS, ADMINISTRATOR, ENVIRONMENTAL PROTECTION AGENCY

Mr. RUCKELSHAUS. Thank you, Mr. Chairman.

My statement will be a summary of two previous statements that I have submitted to the Congress; one to the Senate Committee on Public Works and the Environment; and the other to a counterpart of this committee in the House.

I might say, Mr. Chairman, at the outset that the dialog that occurred a minute ago on tall stacks I think is indicative of the nature of this problem.

When the Clean Air Act was first passed back in 1970, it was aimed at avoiding health effects and environmental effects which were believed to be effects occurring close in to the combustion of fossil fuels and other kinds of problems.

When the approach of building tall stacks as one way of alleviating the ground-level impacts of unwanted pollutants was adopted, it was not thought that the long-range transport of these same pollutants might cause some additional welfare, environmental, or even health effects.

The Congress addressed the issue of tall stacks and how much credit could be given for the construction of tall stacks in some amendments to the Clean Air Act that were passed in 1977.

Those amendments primarily related to how much credit could be given for a stack built so high in terms of the alleviation of the emissions of various pollutants at the ground level.

What we are, I believe, at the very early stages of trying to address is the effects of these same pollutants, whether it's particulate matter, ozone, heavy metals, or acid rain, sulfur oxides, nitrogen oxides on a long-range transport basis.

And the purpose of all this research that is going on that has generated so much scientific debate is to better understand the long-range effect of the pollutants that we have been trying to control very close in to the sources.

The close-in control is aimed at alleviating health effects, aimed at alleviating environmental effects. And what we're finding in lakes, forests and other kinds of areas of scientific research now are some effects, apparently as a result of the long-range transport of these same pollutants.

That there is debate over the effects of these is very similar to the kind of debates that existed over the health effects and environmental effects of these pollutants at more immediate range.

And what we're seeing, I think, is an emerging body of knowledge about the health and environmental effects of the long-range transport of these pollutants. And that's eventually what we may need to be able to deal with as a nation.

But what we're suggesting is that at the current state of our knowledge, we're not sufficiently aware of what these effects are to know how to craft a solution to them that both will resolve the problems and do so in as cost-effective and with as little social disruption as possible in the country.

I think that this dialog that just occurred indicates as much as anything else, Mr. Chairman, what the real nature of this debate is all about.

As I suggested, in recent months I have testified before this committee and others involving this problem, and I won't try to consume this committee's time with another lengthy statement. I'll simply submit those earlier statements with your permission, Mr. Chairman, for the record.

The CHAIRMAN. They will be made a part of the record, following your initial statement.

Mr. RUCKELSHAUS. The impact of acid deposition on the North American environment is of great concern to the administration and to me personally.

Since returning to the Agency, I have spent a great deal of time studying this issue. There is no question that there is an acid rain problem in this country. There is, however, significant uncertainty regarding the scope of this problem, the pace at which damage is occurring, and the specific physical and ecological mechanisms involved.

Any acid deposition control program will represent a major environmental, economic and social investment for the country.

Specific knowledge of where and how to target such a program, how big to make it, and what to expect of it are crucial to ensuring that such an investment is made wisely.

Given the current state of scientific knowledge, the administration is not prepared to recommend additional regulatory action at this time.

Let me emphasize that this does not mean the door is closed. It simply means that before launching the country on an expensive control program, it is necessary to have a better understanding of the scientific, technical, and administrative questions which affect acid rain policy.

We are responding to the need for more understanding in two ways: First, we are more carefully targeting our research by addressing those areas of scientific uncertainty, which are most relevant to policy development, and by consulting with European countries on areas in which they already have a great deal of expertise.

Second, we have sought to expand significantly the size of the Federal Acid Rain Research Program. The administration has requested a total of $127 million in fiscal year 1985 to address these areas of uncertainty; $55.5 million of the administration's budget will go to fund the National Acid Precipitation Assessment Program.

Key projects to be performed by this interagency research effort include a national lake survey and national terrestrial survey, which together will help us to determine the scope of the acid deposition problem, an expansion of our National Trends Network which will provide us with more data concerning long-term deposition trends, and an indepth study of the complex mechanisms by which acid deposition is formed, transported and affects the environment.

In addition, the administration has requested $67 million in fiscal year 1985 for control technology research, and $5 million to study the effectiveness of lake mitigation.

Concurrent with these efforts, we will be working with the States on the complex implementation problems that any acid rain control program will be likely to pose.

The acid rain debate seems to have focused—as I think it did here this morning, Mr. Chairman—on at least two issues: who pays, and how much?

There is, however, a more fundamental question that must be answered: Do we know enough to ensure that what we are proposing will work?

One emerging issue that has assumed greater importance of late, that of damage to forests, is, I believe, illustrative of the importance of reasoned and careful decisionmaking by public policymakers.

Based on a limited amount of data, it appears that over a wide area of the eastern United States, there has been a pronounced decline in tree diameter growth of several species over the past two decades.

This retardation in growth is not correlated with any specific climatic trend, and because it involves a number of species over a wide geographical area, it does not appear to be solely attributable to normal ecological processes.

In high altitudes, a more severe set of symptoms—called "dieback" has been observed. We have seen significant losses in several species of trees. In Europe, different and more extensive types of tree damage have been observed, involving at least 10 species.

We do not know the true extent or meaning of this damage, the rate at which it is taking place, or what factor or combination of factors is causing it.

We do not know if the causes are the same in Europe as in this country. Many investigators believe that several interconnected factors are at work, and that air pollution, of some sort, may be important among them.

Our current knowledge, however, does not tell us whether the offending pollutants are sulfates, nitrates, oxidants, heavy metals or some combination of these pollutants.

This new information, while troubling, raises the possibility that if we act too quickly we may not control the proper pollutant.

This situation illustrates well why waiting for further research to be completed before initiating a control program, is a rational environmental decision.

If, as many believe, sulfate deposition is not a major contributor to forest problems, but oxidants or nitrates are, a significant reduction in SO_2 emissions would have little or no effect on oxident or nitrate levels, and, consequently, would contribute little to the prevention of additional forest damage.

Thus, the uncertainties and gaps in our knowledge are matters of far-more than academic interest. They are directly relevant to our ability to make responsible public policy choices.

In closing, Mr. Chairman, let me reassure you of my determination to forge a better understanding of the causes, effects and solutions to the acid rain problem as quickly as possible.

In my previous testimony on this subject before the House and the Senate, I was asked when we will know enough to make a decision regarding additional controls.

I am sure that many of you have asked the same question. The answer is that I do not know, since I cannot predict what the answers from the research program will be, or precisely when they will be forthcoming.

It should be clear that it is not necessary to have complete or definitive answers to each of the areas of uncertainty before new recommendations can be developed.

As we continue to gain more knowledge and understanding about acid deposition, our ability to predict the results of various control efforts will increase and we will reach a point at which the administration can reasonably make a decision regarding the need for additional controls.

I cannot tell you exactly when that point will come. What I can say is that I take it as an affirmative duty on my part as Administrator of EPA to ensure that we make reassessment of our policy an active and ongoing process, and that I communicate the product of this effort to the key decision makers in the administration and the Congress as soon as appropriate.

The administration has an active program to respond to the research questions and is in favor of finding a solution to the complex problem of acid rain.

When the fundamental scientific uncertainties have been reduced, this administration will craft and support an appropriate set of measures to solve the acid rain problem.

This concludes my remarks, Mr. Chairman. And I know that my colleagues and I would be pleased to respond to your questions after they have made any statements they have.

[The prepared statements of Mr. Ruckelshaus follow:]

STATEMENT OF
WILLIAM D. RUCKELSHAUS
ADMINISTRATOR
U.S. ENVIRONMENTAL PROTECTION AGENCY
BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE
APRIL 30, 1984

Mr. Chairman and Members of the Committee. You have invited me here today to discuss acid rain.

In recent months I have testified before the Senate Committee on Environment and Public Works and before the House Subcommittee on Health and the Environment concerning this important issue. Rather than consuming the Committee's time with another lengthy statement, I would like to submit both of those statements for the record and confine my prepared remarks today to summarizing the positions they set forth.

The impact of acid deposition on the North American environment is of great concern to this Administration and to me personally. Since returning to the Agency I have spent a great deal of time studying this issue. There is no question that there is an acid rain problem in this country. There is, however, significant uncertainty regarding the scope of this problem, the pace at which damage is occurring and the specific physical and ecological mechanisms involved.

Any acid deposition control program will represent a major environmental, economic and social investment for this country. Specific knowledge of how and where to target such a program, how big to make it, and what to expect of it are crucial to assuring that such an investment is made wisely. Given the current state of scientific knowledge, the Administration is not prepared to recommend additional regulatory action at this time.

Let me emphasize that this does not mean the door is closed. It simply means that before launching the country on an expensive control program, it is necessary to have a better understanding of the scientific, technical and administrative questions which affect acid rain policy.

We are responding to the need for more understanding in two ways. First, we are more carefully targeting our research by addressing those areas of scientific uncertainty which are most relevant to policy development, and by consulting with European countries on areas in which they already have a great deal of expertise. Second, we have sought to expand significantly the size of the federal acid rain research program. The Administration has requested a total of $127 million dollars in fiscal year 1985 to address these areas of uncertainty. $55.5 million of the Administration's budget will go to fund the National Acid Precipitation Assessment Program.

Key projects to be performed by this interagency research effort include a national lake survey and national terrestrial survey which together will help us to determine the scope of the acid deposition problem, an expansion of our National Trends Network which will provide us with more data concerning long-term deposition trends, and an in-depth study of the complex mechanisms by which acid deposition is formed, transported and affects the environment.

In addition, the Administration has requested $67 million in fiscal year 1985 for control technology research, and $5 million to study the effectiveness of lake mitigation.

Concurrent with these efforts, we will be working with the states on the complex implementation problems that any acid rain control program would be likely to pose.

The acid rain debate seems to have focussed on two issues: "Who pays?" and "How much?" There is, however, a more fundamental question that must be answered: "Do we know enough to ensure that what we are proposing will work?"

One emerging issue that has assumed greater importance of late--that of damage to forests--is, I believe, illustrative of the importance of reasoned and careful decision-making by public policy makers. Based on a limited amount of data, it appears that over a wide area of the eastern United States, there has been a pronounced decline in tree diameter growth of several species over the past two decades. This retardation in growth is not correlated with any specific climatic trend, and because it involves a number of species over a wide geographical area, it does not appear to be solely attributable to normal ecological processes.

In high altitudes, a more severe set of symptoms--called die-back--has been observed. We have seen significant losses in several species of trees. In Europe, different and more extensive types of tree damage have been observed, involving at least ten species.

We do not know the true extent or meaning of this damage, the rate at which it is taking place, or what factor or combination of factors is causing it. We do not know if the causes are the same in Europe as in this country. Many investigators believe that several interconnected factors are at work, and that air pollution of some sort may be important among them. Our current knowledge, however, does not tell us whether the offending pollutants are sulfates, nitrates, oxidants, heavy metals or some combination of these pollutants. This new information, while troubling, raises the possibility that if we act too quickly, we may not control the proper pollutant.

This situation illustrates well why waiting for further research to be completed before initiating a control program is a rational environmental decision. If, as many believe, sulfate deposition is not a major contributor to forest problems but oxidants or nitrates are, a significant reduction in SO_2 emissions would have little or no effect on oxident or nitrate levels and consequently would contribute little to the prevention of additional forest damage.

Thus, the uncertainties and gaps in our knowledge are matters of far more than academic interest. They are directly relevant to our ability to make responsible public policy choices.

In closing, let me reassure you of my determination to forge a better understanding of the causes, effects and solutions to the acid rain problem as quickly as possible. In my previous testimony on this subject before the House and the Senate, I was asked when we will know enough to make a decision regarding additional controls. I am sure that many of you have the same question. The answer is that I do not know since I cannot predict what the answers from the research program will be or precisely when they will be forthcoming.

It should be clear that it is not necessary to have complete or definitive answers to each of the areas of uncertainty before new recommendations can be developed. As we continue to gain more knowledge and understanding about acid deposition, our ability to predict the results of various control efforts will increase, and we will reach a point at which the Administration can reasonably make a decision regarding the need for additional controls. I cannot tell you exactly when that point will come. What I can say is that I take it as an affirmative duty on my part as Administrator of EPA to assure that we make reassessment of our policy an active and ongoing process, and that I communicate the product of this effort to the key decision-makers in the Administration and the Congress as soon as appropriate.

The Administration has an active program to respond to the research questions and is in favor of finding a solution to the complex problem of acid rain. When the fundamental scientific uncertainties have been reduced, this Administration will craft and support an appropriate set of measures to solve the acid rain problem.

This concludes my prepared remarks, Mr. Chairman. I would be pleased to answer any questions that you may have.

Statement of
William D. Ruckelshaus
Administrator
U.S. Environmental Protection Agency
Before the
Committee on Environment and Public Works
United States Senate
February 2, 1984

Mr. Chairman, Members of the Committee:

The subject is acid rain. I suspect that the members of this Committee have spent more time studying the issue of acid rain than any other before you in the last decade. In the last nine months I have personally met with over 100 groups and individuals representing every conceivable point of view on the same subject. I have spent countless hours reviewing all aspects of the problem ranging from the science, to the available control strategies, to who would pay for reductions of the suspect pollutants, to how you would administer a control program. Out of all this effort one might expect that I could now lay before this Committee a comprehensive solution to which all could repair. Unfortunately, not yet, but I believe we are making progress.

As the President said in his State of the Union speech last week, there is great concern in this country and in Canada about the problem of acid rain. I share that concern as does the President. I am determined to forge an understanding of the causes, effects and solutions to acid rain as quickly as possible. Several members of this Committee already believe we know enough about the problem to fashion a solution. This belief is shared by many in the country. Others in and out of the Congress believe otherwise. On the basis of the current state of scientific knowledge, the Administration is not prepared to recommend additional sulfur oxide controls.

That does not mean the door is closed. It simply means that before launching the country on an expensive and potentially divisive control program, we feel we need more scientific information.

Such questions as the scope and pace of the damage are at the top of the list of our research agenda. In addition, a better understanding of the mechanism whereby deposition affects sensitive areas and of the acidification process itself would be helpful in finalizing any control strategy. We do not believe that pursuing these scientific puzzles as diligently as possible will cause an unacceptable delay. The Administration is in favor of finding a solution to the complex problem of acid rain. When the fundamental scientific uncertainties have been reduced, this Administration will craft and support an appropriate set of measures to solve the acid rain problem.

Make no mistake about it, acid rain is a problem. There are some things we know about it and some we don't. I will try to spell out for this Committee as clearly and as carefully as possible the nature of the problem as we now understand it and what we are doing to enhance that understanding under the mandate from Congress expressed in Title VII of the Energy Security Act.

Since returning to EPA I have made a special effort to assure that the Agency's review and assessment of scientific facts related to our work is separated from a discussion of what should be done in response to these facts. We have characterized this change as separating "risk assessment" from "risk management." Only in this way can the public be sure that EPA's statement of the science is the most objective and unbiased possible.

Separating out risk assessment from risk management is as vital in the area of acid deposition as it is in other fields of our work. This is the way we have pursued the intensive inquiry into the acid deposition problem. I will start this morning with our assessment of the problem.

This Committee has heard extensive testimony on the science of acid rain. I will not try to be exhaustive in discussing what we know or don't know, but will touch only on the points most relevant to the policy deliberations.

State of the Knowledge on Acid Rain

Based on my study of this problem over the last few months, I would summarize what we know about acid rain at this time by the following major points:

- The northeastern United States and southeastern Canada receive rainfall that is, on average, more acidic than rainfall elsewhere in the country. Rainfall in much of the Northeast has a pH of 4.2 compared with rainfall with a pH of approximately 5.0 to 5.6 elsewhere.
- This same region is located downwind from the area in the U. S. and Canada which has the greatest density of sulfur oxide emissions.
- There are acidified, clear lakes (otherwise unaffected by man's activities) in areas which receive heavy acid deposition. In contrast, there are few, if any, affected lakes where acid deposition is less.

- Most scientists active in the field believe that acidic deposition has been a major contributor to acidification of these lakes.

- Not all areas in the eastern United States are sensitive to acid deposition. The areas at risk are those which both receive high levels of acidic deposition and have limited alkalinity or buffering capacity.

- We are seeing damage to some tree species in parts of the United States. Several environmental stresses, including acid rain, ozone, trace metals, and drought, may be interacting or acting alone to cause these effects.

Gaps In Our Information

As helpful as these points are, they do not, of course, give a full picture of acid deposition. Our knowledge is incomplete. Congress recognized this in December, 1980, when it passed Title VII of the Energy Security Act, authorizing a 10-year research program on acid deposition. The National Acid Precipitation Assessment Program (NAPAP) is now underway. We have had the benefit of approximately two years of research under that program.

I wish, as I am sure you do, that those two years could have eliminated any fundamental gaps in our knowledge of the causes and effects of acid rain. We are making progress, and we are benefiting from this research mandate. We must recognize however that for a program of this magnitude and complexity, the research effort is still at a very early stage.

Let me highlight a few of the areas where the unsettled state of knowledge appears to be particularly important to the development of policy.

The Scope of the Problem: We really do not know the extent of damage to our aquatic resources from acid deposition. Based on the data available, we know of approximately two hundred lakes, almost all of which are in the Adirondacks, that are acidified nationwide. This covers a very small percentage of the surface water of the country. I have no doubt that others will be identified as acidic. But, we have not yet made a systematic search for them. Certainly our water quality models would suggest that such additional surface waters susceptible to damage by acid deposition do exist. We need to get a more accurate picture of the scope and extent of this damage.

Trends: Our knowledge of the pace at which the environment is changing is very thin.

There are four components of the environment where trends are particularly important: (1) the sulfate and nitrate concentrations in deposition, (2) the pH of rainfall, (3) the sulfate and nitrate concentration in water bodies, and (4) the rate at which water bodies are becoming acidified.

In the area of deposition trends, efforts to monitor trends began in earnest in the United States during the late 1970's. Today, the National Trends Network, includes 120 monitoring sites in 48 states, including most of the early monitoring sites established in the 1970's. Several more years of data are needed before any conclusions can be reached from this network about trends in the sulfate and nitrate concentration in precipitation.

Longer time trend analysis has been made on the basis of results from the Hubbard Brook Ecosystem Study, which ran from 1963 to 1977. The Hubbard Brook data indicate a decrease in sulfate concentrations and an increase in nitrate concentrations in rainfall, but the data did not indicate any trend in pH in the rainfall during the same period.

These limited deposition data suggest that sulfate and nitrate concentrations in deposition reflect changes in emissions and that the net result of decreasing SO_2 emissions and increasing NO_x emissions has been a relatively stable average pH of precipitation.

Turning to the sulfate and nitrate concentration in water bodies, the U.S.G.S. recently published its study of water-quality records collected over a 10 to 15 year period from the Hydrologic Bench-Mark Network, a nationwide network of sampling stations in predominately undeveloped stream basins. The data indicate declines in stream sulfate in the Northeast and increases in sulfate in a number of sites in the Southeast and the West. The U.S.G.S. concluded that the geographic trends in sulfate concentrations at Bench-Mark Stations approximately coincides with trends in emissions of SO_2 during the period from 1965 to 1980. In contrast, the trends in pH did not follow any pattern. Among the explanations for the lack of a pH trend are the possible effects of nitrate deposition on pH and the neutralizing capacity of many basins which resist changes in pH.

Our knowledge of the trends in the number of water bodies becoming acidic is even thinner. Recent data show a number of lakes having low pH and high sulfate concentrations. Most scientists believe that condition to be the result of acid deposition. We have other data which identify a number of acidified lakes in areas of high acid deposition. These data show a number of other lakes with low alkalinity measurements. But we do not have any long-term data to indicate how the present chemistry of these lakes was established, or over what time period.

Obviously whether we are dealing with a rapidly deteriorating situation or a decades-long phenomenon is important in deciding what to do.

Source/Receptor Relationships: No discussion of acid rain would be complete without a discussion of the relation between the sources of emissions and the sensitive receiving areas. Our present knowledge is based, as you know, on very simplified transport/transformation models. The recent National Academy of Sciences panel dealt with this issue at length. Everyone, including the Academy, agrees that further research in this area is important. It is fair to say that current models and data analysis cannot accurately predict the impact of a particular group of emission sources on particular receiving areas, several hundred miles away. The assumptions upon which these models are based tend to produce results which indicate that local sources are more important than distant sources of the same size. The relative importance of local versus distant sources as well as many other factors have to be addressed in order to adequately predict source/receptor relationships.

The Role of Dry Deposition: Related to the transport/transformation issue is the quantitative and qualitative relationship between "wet" and "dry" deposition. To date most of our data relate to "wet" deposition. We do not know the extent of "dry" deposition that is occurring because reliable field monitoring techniques are not yet available. From the data available, we estimate that the amounts of dry deposition occurring may be from one half to 7 times the level of wet deposition, depending upon the particular location. In remote areas, estimates are that the dry deposition contribution ranges from equal to half that of the wet deposition. We should learn more about all forms of deposition, particularly dry deposition, if we are to control the precursors to acid rain effectively and efficiently.

The Acidification Process: Over the last year and a half, as the result of new knowledge from our present acid rain research program, an issue has been emerging from the scientific and academic communities; it involves two different hypotheses about how the acidification process actually takes place in watersheds and at what pace. For the purpose of this discussion I'll call them the "delayed response" hypothesis and the "direct response" hypothesis.

The "delayed response" hypothesis holds that the acidification of lakes is a long-term process. The accumulation of acid deposition over many years eventually depletes the available acid neutralizing capacity in the surrounding watershed. As that point is reached, more and more acidity will flow unneutralized into the waterbody, leading to rapid acidification.

The implication of this hypothesis is that unless acidic deposition is decreased, we will see more and more lakes and streams becoming acidic as the neutralizing capacity is depleted in individual watersheds.

The "direct response" hypothesis is suggested as especially applicable to the Northeast. It holds that acidification of lakes is more immediate than long-term in nature. Under this hypothesis, the sensitivity of a watershed depends upon the rate at which it can neutralize acidity, not upon some limited neutralizing alkalinity capacity. Equilibrium between the rate of acid input and output is established fairly rapidly as precipitation passes through the receiving soils.

This hypothesis implies that the acidification which has already occurred in our lakes and streams is all that will occur unless future levels of acidic deposition increase. I am told by our scientists that there is not enough empirical evidence today to substantiate either of these hypotheses. There are obvious policy implications if the latter hypothesis is true.

Effects On Forests: The final area where additional research is especially important is that of effects on forests. Beyond knowing that there has been an apparent decline in the condition of some of our forests, we know little about the scope of the problem or its causes. Acid deposition may be a primary cause, and then again it may not. We need to examine not only the direct impact of the deposition on the foliage but also the indirect impact of deposition through changes in chemistry of the soils.

Federal Actions to Date

The Federal Government has been addressing the problem of acid rain since the early 70's, but not in any concerted way until 1981. Any impact we have had on acid rain precursors (sulfur dioxide and nitrogen oxides) is an indirect result of our efforts to control these pollutants for health or other effects under the Clean Air Act.

Nevertheless a significant reduction of sulfur dioxide (SO_2) has occurred. SO_2 emissions peaked in the 70's and have been dropping since. Our analysis shows that, absent these efforts, sulfur oxide emissions nationwide would have been 50% greater in 1980 than they actually were -- some 40 million tons versus 27 million. This reduction is even more significant since electrical generation, the source of most of the sulfur oxide emissions, increased 50% between 1970 and 1980.

The recent U.S.G.S. data on the decreased sulfate loadings in Northeastern streams gives me hope that this reduction of sulfur oxide emissions is, in fact, working to reduce sulfate deposition on our sensitive resources.

Until 1981, research on the subject of acid rain had been an unfocused set of projects spread among the many Executive departments and agencies. Congress's call for a national research program has changed all that. We now have an interagency research program administered by a Task Force chaired jointly by EPA, the Department of Agriculture, and the National Oceanic and Atmospheric Administration (NOAA). Other agencies, including the Department of Energy and Interior, are active participants.

Because this interagency research program is so vital to the decision-making process in the area of acid rain, I wanted to be certain that the research effort was organized and managed as well as possible.

Accordingly, soon after returning to EPA last spring, I convened, along with the Secretary of Agriculture and the Administrator of NOAA, an ad hoc panel under the auspices of EPA's Science Advisory Board to review the whole Federal acid rain research effort--to assess its adequacy, review its scope and management, judge its relevance to policymaking, and recommend possible improvements. The panel's Chairman was John Deutch, Dean of Science at the Massachusetts Institute of Technology. I have already provided this Committee with a copy of the panel's report. We are now in the process of implementing their recommendations. In fact, the Administration's acid rain budget for Fiscal Year 1985 is a direct result of those recommendations.

Another important effort underway at EPA for some time, of which I believe you are aware, is the development of the Critical Assessment Document Review Papers on the Acidic Deposition Phenomenon and Its Effects. Trying to make a wise decision when we are confronted with stacks and stacks of individual scientific studies, is difficult to say the least. Each one may be a sound piece of work, but they are often not integrated with one another. At the request of our Science Advisory Board, we have been working with a group of over 50 scientists to produce a scientific, peer-reviewed, compilation of these studies. It will be a document all of us can use to determine the current state of the science in the many disciplines relevant to acid rain. This report, including summaries of each of its major chapters, has undergone extensive peer review and will be published in final form this Spring.

This effort is unique in that it provides, I believe, the most definitive integration and synthesis to date on the full range of issues critical to acid rain, including: precursor emissions; pollutant transformation to acidic compounds; pollutant transport; pollutant deposition; and the effects (both measured and potential) of acidic deposition. This work by the scientific community, led by the Interagency Task Force, has assisted my effort to assess the state of the science over the last several months.

Future Actions

The budgetary history of the National Acid Precipitation Assessment Program is impressive:

Fiscal Year	$ million
1980	$11.5
1981	$13.0
1982	$18.2
1983	$22.6
1984	$27.6
1984 Supplemental Request	$5.5
1985 Request	$55.5
TOTAL:	$153.9

This money is aimed at increasing our knowledge of the causes and effects of acid rain. I have attached a summary of this research effort.

Important to a cost-effective control strategy will be success in developing new technology. The Administration's budget includes 67 million dollars for this purpose in Fiscal Year 1985.

The President has also committed 5 million dollars for an experimental program to help restore the buffering capacity that has been reduced in affected lakes over the years. This program, to be administered by the Fish and Wildlife Service, will be closely tied to our overall research effort and will build upon existing experience. A number of countries in Scandinavia have had some experience in employing lake restoration techniques. The States will be involved in the design and implementation of this program. It will involve restoration of a number of lakes. We will seek to protect certain sensitive lakes from further deterioration and help others recover from dangerously low pH levels. While we do not view restoration as a permanent or long-term solution to the acid rain problem, it may prove to be an essential component to addressing acid rain now as well as in the future.

With the $55.5 million for the Interagency research effort, $5 million for effects mitigation, and $67 million for control technology research, the President is requesting a total of $127.5 million in FY 1985 for efforts to address acid rain.

New Research Initiatives:

Now I would like to focus on how we have been using our research resources to fill some of the key information gaps I have already identified.

Scope: To improve our knowledge of the effect that acid rain has had on the nation's aquatic resources, I directed the EPA staff last November to immediately begin the design and implementation of a National Lake Survey to measure the water quality of some 2000-3000 lakes located in areas of the nation we believe are potentially sensitive to acid deposition. This includes lakes in all of the sensitive regions of the United States. Pilot sampling has already been carried out in New England and New York to test out field procedures. These water quality measurements are scheduled to be completed by the end of 1984 and will be the first phase of a planned three-phase program. The second phase will extend the survey to the chemistry of streams in these areas and will also include a biological survey of a subset of the lakes in the initial survey. The final phase will be the long-term monitoring of a representative number of lakes and streams to record trends in the chemistry and biota of these waters as well as acid deposition.

This study is designed to answer these important questions: (1) how many surface waters today show evidence of acidification? (2) what influence does acid rain have on surface water chemistry and biota? (3) what percent of these sensitive surface waters now support fish? and (4) what impact do changes in acid deposition levels have over time, on lake acidity?

Trends: Our planned research program includes several major elements designed to fill the gaps in trend data which I outlined earlier:

Sulfate and Nitrate Concentrations in Deposition: In Fiscal Year 1985, the wet deposition monitoring effort will expand the number of wet deposition monitoring sites under the National Trends Network. The original network was to have had approximately 150 sites established by the end of 1985. With the additional research funding, the network will be expanded by 40 to 50 additional sites within the same time period. The expanded number of stations will provide the deposition data required at the long-term lake and ecological monitoring sites.

Up to this time we have had no measured data on dry deposition. The research program calls for the establishment of a number of pilot dry deposition monitoring sites. These sites will be part of an accelerated effort to develop and validate dry deposition monitoring techniques, and they will provide the first data on dry deposition in 1985.

pH of Rainfall: This same expansion of the National Trends Network will give us much better information on the trends in pH of rainfall across the country.

Sulfate and Nitrate Concentration in Receptors, Including Water Bodies: Current plans call for the establishment of 40 to 50 long-term environmental effects monitoring sites. These will include Lake Survey phase three sites and a number of additional sites where we will monitor for terrestrial, soil and surface water effects. They will be coordinated with the additional National Trends Network wet deposition monitoring sites. These data will provide extensive information at the process level on trends in chemistry and effects. These sites will be established in 1985 and will be designed to provide an early warning of any dramatic environmental changes that might occur.

Number of Water Bodies Becoming Acidified: The National Lake Survey to be carried out this year will provide us a baseline of water bodies now acidified. It will also provide us with the information to select long-term monitoring sites, which will be representative of watersheds nationwide for the purpose of discerning trends in lake acidification.

Source/Receptor Relationships: To attempt to help resolve important questions regarding sources and receptors, we plan to conduct field studies to try to relate pollutant sources to acidic deposition. Studies now underway should help us understand the processes that govern the formation of acidic pollutants in the atmosphere, and their transport and deposition in sensitive areas.

We are also planning a large-scale atmospheric investigation to obtain empirical data on source/receptor relationships. As part of this research, a major experiment has just been completed in which inert tracers were released in the Midwest and Canada and then tracked in air masses moving across the Northeastern U.S. and Southeastern Canada. Initial findings will be available later this year.

The Acidification Process: We are asking the National Academy of Sciences to convene a scientific meeting as soon as possible to review the two hypotheses regarding aquatic acidification (the "delayed response" and "direct response" hypotheses) and determine whether they are legitimately in dispute, and, if so, to recommend additional research initiatives to help resolve the areas of disagreement.

Effects on Forests: In order to learn more about possible terrestrial effects, we are planning extensive long-term studies to determine whether acid rain has caused damage or changes in rate of growth and species composition in forests. Detailed planning for the forest survey began in 1983. The forest survey is being designed now, and it should be available for implementation in about a year.

The FY 85 research program includes a large expansion of the effort on terrestrial effects. In addition to the forest survey which I just described, the program calls for extensive new research to examine problems of nutrient leaching, metal mobilization, soil chemistry, and the physiology and pathology of trees.

Obviously this testimony cannot include all the research in which we are engaged, but I have sought to highlight how we are attempting to fill some gaps in our knowledge important to the development of policy.

In conclusion let me make two points.

First, I am sure you join me in feeling a certain frustration when it comes to the timeliness of scientific research results. I know I want, and I am sure you want, information right when we need it on which we can base sound policy judgments. But often the information we want and need is not there. Had we started all of this research ten years ago we might have avoided much of the uncertainty and inevitable emotion which now complicates our successful development of policy on this issue.

It is not the fault of the scientists. Key scientific questions -- which in the case of acid rain include effects on forests, water, and soils -- require substantial periods of time to investigate and answer. Often historical data are found to be sketchy and incomplete. The physical and chemical phenomena which the scientists deal with in studying the causes and effects of acid rain are extraordinarily complex. In acid rain research, it is going to be difficult to reduce the time the scientists need to accumulate information, sort it out, make supportable scientific judgments, and draw final conclusions. I pledge to this Committee my best efforts to accelerate the time when we can get needed answers.

Finally, we must understand that delaying a control strategy decision to gain better information involves the question of whether we are dealing with an emergency or a phenomenon that can be addressed over a longer period of time.

Obviously if we have more time to reduce precursor emissions, it can be done with less expense and social disruption to the country.

Our research effort and our caution in recommending a control strategy are aimed at both the questions of trends and expense. If we find the trends are gradual or, under the "direct response" theory, stable with regard to the lakes, that will suggest one course of action. If not, then we may need to act faster and with less knowledge of causes and effects and of the advanced technology necessary to hold down the expense and disruption of a large control program.

We are working hard to understand the trends. With a national monitoring system in place, we will no longer be in the dark as to what is happening and how fast.

In the meantime, EPA is working with the states through STAPPA and ALAPCO to design a model control program to ensure we are ready should the facts warrant action.

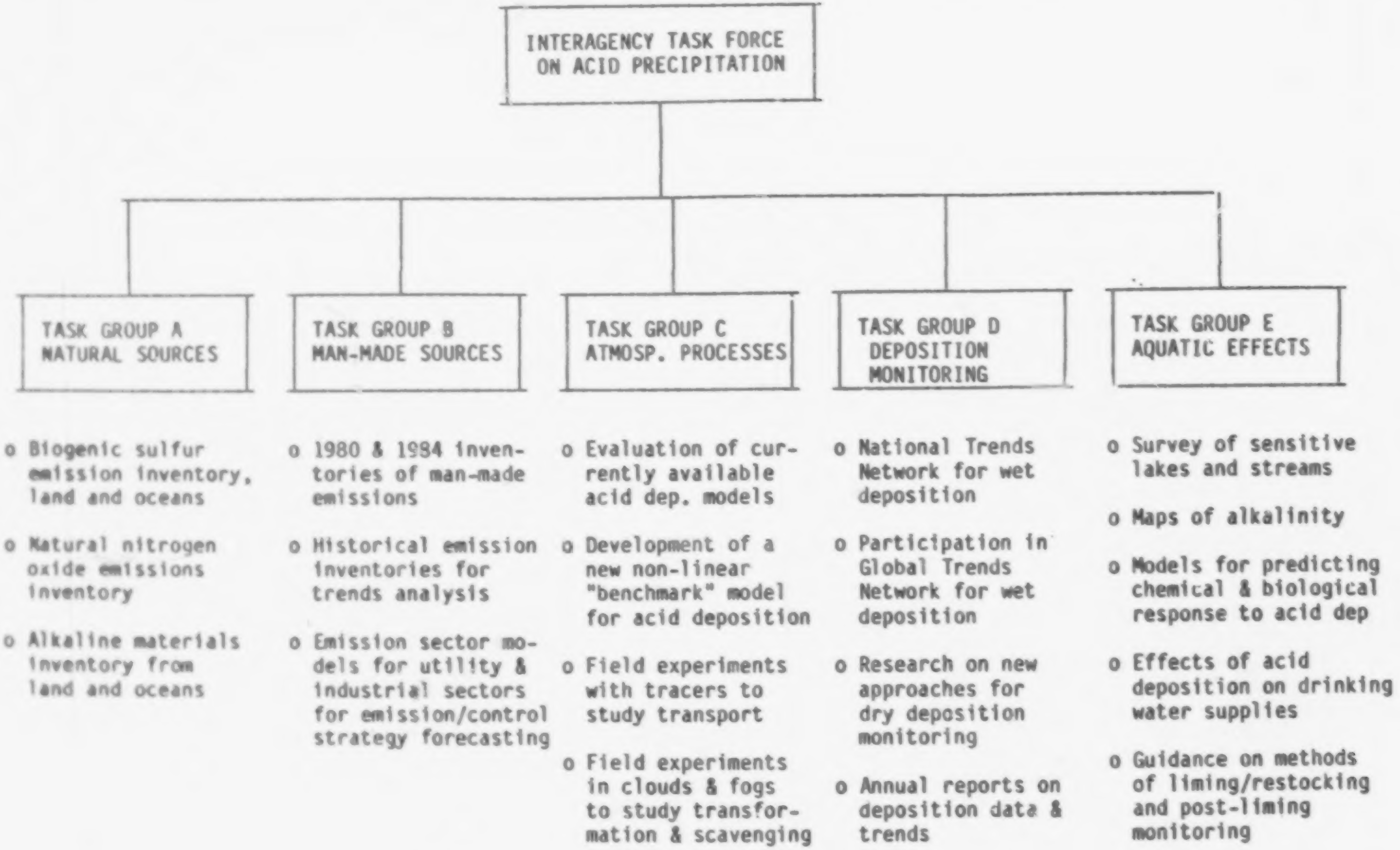
Mr. Chairman, I recognize this issue has been a most divisive one between this Committee and the Administration. As in other areas affecting this Committee and EPA, I will do everything I can to help smooth the way toward the development of sound public policy.

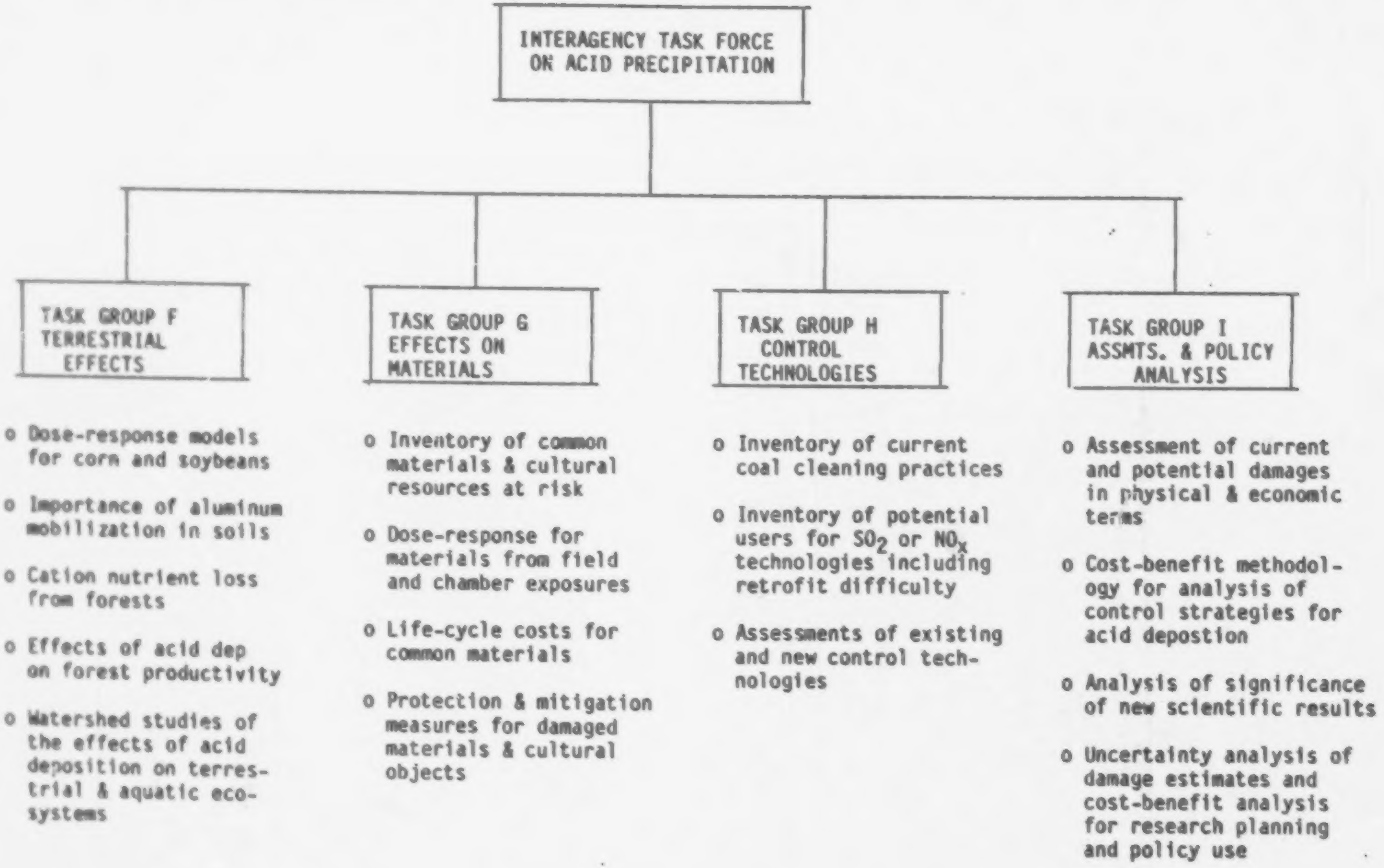
This issue has the potential for dividing the country along regional lines and creating much rancor and little progress.

I believe if we all approach it with good will and a recognition of the legitimate concerns of people in every section of the country and our neighbors to the north, we can solve it.

It is in that spirit that I offer this testimony and pledge my best efforts to resolve our differences.

* * * *


INTERAGENCY TASK FORCE ON ACID PRECIPITATION
TASK GROUP A NATURAL SOURCES
o Biogenic sulfur emission inventory, land and oceans
o Natural nitrogen oxide emissions inventory
o Alkaline materials inventory from land and oceans
TASK GROUP B MAN-MADE SOURCES
o 1980 & 1984 inventories of man-made emissions
o Historical emission inventories for trends analysis
o Emission sector models for utility & industrial sectors for emission/control strategy forecasting
TASK GROUP C ATMOSP. PROCESSES
o Evaluation of currently available acid dep. models
o Development of a new non-linear "benchmark" model for acid deposition
o Field experiments with tracers to study transport
o Field experiments in clouds & fogs to study transformation & scavenging
TASK GROUP D DEPOSITION MONITORING
o National Trends Network for wet deposition
o Participation in Global Trends Network for wet deposition
o Research on new approaches for dry deposition monitoring
o Annual reports on deposition data & trends
TASK GROUP E AQUATIC EFFECTS
o Survey of sensitive lakes and streams
o Maps of alkalinity
o Models for predicting chemical & biological response to acid dep
o Effects of acid deposition on drinking water supplies
o Guidance on methods of liming/restocking and post-liming monitoring



INTERAGENCY TASK FORCE ON ACID PRECIPITATION

TASK GROUP F TERRESTRIAL EFFECTS

- Dose-response models for corn and soybeans
- Importance of aluminum mobilization in soils
- Cation nutrient loss from forests
- Effects of acid dep on forest productivity
- Watershed studies of the effects of acid deposition on terrestrial & aquatic ecosystems

TASK GROUP G EFFECTS ON MATERIALS

- Inventory of common materials & cultural resources at risk
- Dose-response for materials from field and chamber exposures
- Life-cycle costs for common materials
- Protection & mitigation measures for damaged materials & cultural objects

TASK GROUP H CONTROL TECHNOLOGIES

- Inventory of current coal cleaning practices
- Inventory of potential users for SO_2 or NO_x technologies including retrofit difficulty
- Assessments of existing and new control technologies

TASK GROUP I ASSMTS. & POLICY ANALYSIS

- Assessment of current and potential damages in physical & economic terms
- Cost-benefit methodology for analysis of control strategies for acid depostion
- Analysis of significance of new scientific results
- Uncertainty analysis of damage estimates and cost-benefit analysis for research planning and policy use

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ACID RAIN FACTS

The following fact sheets provide information on the Federal government's Acid Rain program:

- What Causes Acid Rain?
- Effects of Acid Rain
- Acid Rain Research Overview

In addition, information on the National Lake and Land Surveys and the recommendations of the Ad Hoc Committee reviewing the National Precipitation Assessment Program (NAPAP) is available from the EPA Office of Public Affairs, phone (202) 382-4355.

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Acid Rain Facts

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What Causes Acid Rain?

Overview

Acid rain is the term used to describe a chain of complex chemical, atmospheric and environmental processes that start with air pollutant emissions from utilities, industry, and motor vehicles as well as natural sources. When these emissions interact with sunlight and water vapor in the air, they are changed into acidic compounds that may be transported long distances to other areas and then are deposited with rain, snow or dust. The processes of chemical transformation and transport are subjects of intensive continuing research.

Sources of Acid Rain

Normal rainfall is slightly acidic from a variety of natural sources such as certain forms of biological processes, volcanic activity, sea spray, lightning, and many other phenomena of nature. Studies indicate, however, that man-made activities are the major contributors to the increased acidity of rainfall occurring in the northeastern United States.

Acid rain precipitation and dry deposition found in the eastern United States result primarily from the emissions of two pollutants:

Sulfur dioxide (SO_2), which is produced mainly from the burning of coal and oil. Utilities and industry contribute about 90 percent of the total sulfur emissions in the eastern United States. About 70 percent of the total comes from electric utility plants.

Oxides of Nitrogen (NO_x), a pollutant specifically associated with high-temperature combustion. Natural sources are estimated to be less than 10%. Over 60 percent of man-made NO_x emissions in the eastern United States come from electric utilities and motor vehicles.

While public concerns about acid rain are most often focused on SO_2 emissions, the possible influence of NO_x cannot be ignored. Oxides of nitrogen have serious effects on the rates of oxidation in the atmosphere and potential effects on the acidity of surface waters.

Acid Rain Transport

SO_2 and NO_x emissions can cause more than a local problem because of the distances they may travel. The most frequently discussed transport route is the movement of these emissions from the industrial midwest to the northeastern United States. While such long-range transport does occur, a great deal of the emissions fall close to the source of emission or nearby.

- Major factors influencing movement include the speed and direction of the winds.
- Pollutants entering the atmosphere at a relatively high level (as from tall stacks) generally are carried longer distances than those emitted at lower levels.
- Transport of pollutants can be greatly affected by cloud transport and cloud chemistry.

In general, the closer a source is to an area receiving deposition, the greater its contribution to deposition per unit of emission.

The Transformation Process

As they move through the air, emissions may undergo certain chemical changes. SO_2 and NO_x emissions can be oxidized and transformed into acidic sulfates, sulfuric acids and nitric acids. The rates at which the transformations occur can vary greatly depending upon the presence of other pollutants, such as hydrocarbons, in the atmosphere. The complex chemistry is not well understood. As a result it not possible to predict changes in deposition that might result from changes in emissions.

Deposition of Compounds

After pollutant materials are transported and possibly transformed to acidic compounds, they ultimately are deposited back on land and water as gases, particles or as part of rain and snow. The relative contribution of dry versus wet is important for purposes of control strategies. Research is underway to determine the relative importance of these diverse patterns of deposition.

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Acid Rain Facts

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Effects of Acid Rain

Overview

"Acid rain" is the common name given to acidic or acid-forming compounds deposited from the atmosphere into the environment in either dry or wet forms.

The major issues concerning acid rain are the adverse effects it may have on the ecology of lakes, rivers and streams. Other areas of heightened concern are acid rain's effects on forests and crops, man-made materials, and human health.

While some conclusions about the effects of acid rain are generally accepted by the scientific community, many others are not.

The Factors of Acidity and Alkalinity

The best measurement of an area's sensitivity to acid rain is alkalinity. Alkalinity may be thought of as acid-neutralizing ability. Soil and water with high alkalinity provide a strong buffering effect that tends to neutralize or offset acidic compounds. Areas with low alkalinity are less capable of resisting acidification.

Lakes and Streams

Scientists have used alkalinity data on surface waters to identify and describe areas where lakes and streams may be vulnerable to damage from acid rain. Field studies have confirmed acidification or increased acidity in lakes and streams with low alkalinity.

Attempts to determine the progression of acidity in some lakes have also been made from field studies, long-term water quality data, fish population declines, and lake sediment studies. To date, the information gathered has been inadequate to draw conclusions with regard to trends.

There appears to be a critical point in the process, however, at which acidification suddenly occurs. The answers to the questions of how long it takes either to acidify or for acidified lakes to recover are also uncertain. Estimates range from five years to several decades.

The identified lakes that have been most seriously affected by acidity to date are located in New York State's Adirondack Mountains.

The mechanism and pace by which the these lakes became acidified is uncertain. The cumulative effect hypothesis holds that the lakes have changed over many years, the process hastened by such factors as a weak buffering capacity in the surrounding watershed. A second hypothesis suggests that acidification was more immediate, determined by a "dynamic equilibrium" that developed rapidly between precipitation, the soil and water in the watershed. This hypothesis suggests that we have seen the damage that will take place from the present level of deposition. Therefore, unless deposition increases, no further damage would be expected.

Forests and Crops

There is evidence of deterioration in forests, but the role, if any, of acid rain has not been positively identified. Red spruce, Norway spruce and beech trees have shown reduced growth in the northeastern United States and in Europe in recent years. Acid rain is one possible cause but drought, disease and other pollutants could also be involved.

Materials

Experience over the last century in both European and North American cities has shown that air pollutants hasten the deterioration of buildings, statues, and other materials. Since materials naturally degrade, to some extent, with time, it is important to differentiate between normal weathering and deterioration worsened by air pollution. It is especially difficult to distinguish between the relative damage caused by one pollutant versus another pollutant or combination of pollutants.

The particular role played by acid precipitation in the degradation of materials is still a major unknown. This is especially true for the acid depositions stemming from long-range transport of air pollutants. One suspected mechanism for damage to surfaces is the dry deposition of sulfates and sulfur dioxide, which subsequently becomes wet because of rain or humidity. This leads to the formation of sulfuric acid. Such dry deposition would be from nearby sources.

Human Health

Health risks to humans from direct contact with acid deposition are believed to be low at present levels. Certain risks, however, may be associated with acid fog if highly acidic particles are inhaled. The acidity of fog tends to be greater than that of rain. As with other effects of acid rain, research is needed to enable firmer conclusions.

Indirect effects on human health could occur if acid depositions dissolve metals that could later be ingested through the food chain or drinking water. Evidence to date reveals no significant problems.

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Acid Rain Facts

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Research Overview

NAPAP and Acid Rain Research

The Federal research effort in acid rain is coordinated by the National Acid Precipitation Assessment Program (NAPAP), established by the Energy Security Act in 1980 to conduct a 10-year investigation of the extent and causes of acid deposition. The research program began in 1981, with a total interagency budget of $13 million; by FY84, this figure had grown to $28.8 million, and there is a $55.5 million request for FY85. EPA strongly supports the NAPAP effort.

The proposed NAPAP program for FY84 and 85 contains important changes. The new emphasis reflects the need to obtain, those research results that will enable us to resolve the acid deposition issue in an acceptable scientific and technical manner. The propose changes in the NAPAP and EPA research programs derive largely from from the recommendations of an Ad Hoc Committee, set up at the request of William D. Ruckelshaus in August 1983, chaired by Professor John Deutch, Dean of Science at Massachusetts Institute of Technology. As a result of its review of the NAPAP program, the Ad Hoc Committee has made a number of recommendations for change in the areas of funding, research focus, management, and technical review and support.

Budget

The Ad Hoc Committee recommended a doubling of the NAPAP budget in FY85. The Committee believed such an increase would be adequate to provide funds for critical research areas, but measured enough to avoid an over-extended research budget that would out-distance the ability of science to respond. The President's budget seeks to implement the Committee's recommendation. The proposed budget for NAPAP in FY85 is $55.5 million, nearly doubling the FY84 budget of $28 million.

Program

As a result of their review of the NAPAP program, the Deutch Committee recommended that funding for research in several critical areas be significantly increased. Five areas in particular were found in need of substantial increases in funding: (1) defining the resources at risk from acid deposition; (2) long-term intensive studies of environmental response; (3) expanded ambient air monitoring; (4) development of dry deposition monitoring techniques; and (5) field verification of source-receptor models. Approximately $18 million of the proposed FY85 increase is earmarked for research in these five areas.

New National Surveys

The Administration and EPA are requesting a $5.5 million supplement to the FY84 budget for the first phase of a National Lake Survey. The purpose of the survey is to determine much more precisely the number of lakes and streams that have been acidified or may be at risk from acid deposition. The monitoring program put into place by this survey will provide insight into trends of acidification. A national survey of forests affected or endangered by acid rain is also proposed for funding as part of the increased budget in FY85.

Management

The Deutch Committee made several major recommendations for change in the management structure and operations of NAPAP. One of the most important was that EPA establish within its research program a special office devoted solely to the acid deposition problem. Administrator Ruckelshaus has decided to implement that recommendation immediately. Action has already been initiated to create a new office to focus on acid deposition research and assessment. The headquarters and laboratory personnel in this new office will be responsible for planning and carrying out, in cooperation with NAPAP, the greatly expanded EPA research program planned for FY85. EPA's research budget is proposed to increase from $15 million in FY84 to about $34 million in the President's request for FY85.

Technical Review and Support

The Deutch Committee recommended that the NAPAP Program establish a standing technical advisory committee to evaluate ongoing research and future planning. EPA is already working with NAPAP to implement this recommendation. Just as important, the Committee pointed out the need for EPA to have day-today access to the best scientific expertise in the country as questions arise from new research findings. In response to this need, EPA is now working with the National Academy of Sciences to set up a standing committee of experts on acid deposition. This committee will provide the Administrator with advice on the myriad scientific issues that will continue to characterize research on acid deposition.

STATEMENT OF
WILLIAM D. RUCKELSHAUS
ADMINISTRATOR
U.S. ENVIRONMENTAL PROTECTION AGENCY
BEFORE THE
SUBCOMMITTEE ON HEALTH AND THE ENVIRONMENT
COMMITTEE ON ENERGY AND COMMERCE
UNITED STATES HOUSE OF REPRESENTATIVES
MARCH 29, 1984

Mr. Chairman and Members of the Subcommittee. You have invited me here today to discuss acid rain, the regulation of hazardous air pollution, and other issues related to the reauthorization of the Clean Air Act.

In recent months I have testified before the Senate on acid rain and before another subcommittee of this Committee on hazardous air pollutants. Joseph Cannon, the head of our air program, stated our views to the Senate last month on a number of additional Clean Air Act matters. I would like to submit all three statements for the record and confine my prepared remarks today to summarizing and in a few cases amplifying the positions they set forth.

Let me begin with acid rain. There is no question that there is an acid rain problem in this country. There are questions about the scope of that problem, the pace at which damage may be increasing, the precise way damage occurs, and the best ways to correct it.

There are gaps in our knowledge in at least four areas that are relevant to forming a sound acid rain policy.

The first, and perhaps most basic, gap involves the scope of the problem. We really do not know the extent of the damage presently caused by acid deposition. A limited number of lakes have been surveyed and some of those have been found acidic, but even here, no comprehensive inventory exists.

Second, we don't know at what pace this observed damage has occurred. Knowing whether we face a decades-long problem or a more rapidly deteriorating situation is important for the development of sound policies. We do know that a major contributor to the acidity of rainfall, sulfur oxides, has declined by more than 15 percent since the passage of the Clean Air Act. Sulfur oxides are projected to remain at roughly current levels until the turn of the century if we impose no additional controls.

Third, we are uncertain whether or to what extent present levels of damage may be getting worse as a result of current levels of emissions. While our data are sparse it tends to show that the acidity of rainfall in the eastern United States has stayed essentially level for the past twenty years. If it is the rate of deposition that determines the extent of damage in particular watersheds, those watersheds may have reached a steady state in which no more damage will occur unless emissions increase, since the rate of deposition has held steady or decreased over the last few years in the Northeast. If it is the accumulated deposition that matters for a watershed, then damage may still be increasing, even though the rate of deposition remains the same.

At my request, a panel of the National Academy of Sciences has reviewed this question of the acidification process for surface waters. I recently met with this panel. As I understand the matter, their preliminary conclusion is that continued deposition at the current rate is unlikely to have any additional impact in watersheds where the soil has a high ability to neutralize acid deposition, or in watersheds whose rate of acidification is at equilibrium with the rate of acid deposition. It may matter for those watersheds where the soil's neutralizing capacity is moderate and not readily renewed, and thus might be exhausted by repeated stress from acid rain. We have very little idea how many watersheds fall in this category.

Fourth, and finally, there are gaps in our knowledge of where the acid deposition in any given area comes from. This is the source-receptor problem. Our current atmospheric models cannot adequately predict the impact of particular sources on particular receptor areas. Further, though much acid deposition comes down in a dry form, the techniques to measure this dry deposition are still under development.

These uncertainties and gaps in our knowledge are matters of far more than academic interest. They are directly relevant to responsible public policy choices.

Any acid deposition control program will represent a major environmental, economic, and social investment for this country. Knowledge of how and where to target that program, how big to make it, and what to expect from it, will be crucial in assuring that that investment is wisely made.

Any control program will be costly. If that were not so, the Congress, the Administration, and the American people would not have been discussing it so passionately for the last several years. Before large sums of money are committed to controls, we should have as clear a picture as possible of what we are getting for this investment. Our research program under the National Acid Precipitation Act is aimed at closing these gaps.

In December 1980, Congress set up the National Acid Precipitation Assessment Program in Title VII of the Energy Security Act. With that legislation as a base, we are now greatly expanding our research efforts to deal with the gaps in our knowledge, and to put our country in a better position to recommend targeted and efficient policies.

The Administration is requesting a total of $127 million dollars in fiscal year 1985 to deal with acid rain. $55.5 million of this will go to an interagency research effort administered by EPA, the Department of Agriculture and the National Oceanic and Atmospheric Administration, and the balance will go to research on control technology and to effects mitigation.

To better understand the scope of the problem, this fall we will survey some two to three thousand lakes in sensitive areas. In succeeding years we will examine stream chemistry in these regions and the general biology of some representative watersheds.

Our national trends network, which monitors wet deposition, has been put in place and will be expanded in the next few years. We are also developing a monitoring network for dry deposition. These efforts should give us a much better idea both of the nature and extent of total deposition, and will eventually reveal long-term deposition trends.

As I mentioned earlier, the National Academy of Sciences is assisting us in reviewing the scientific evidence regarding the mechanisms of acidification of surface waters. I have asked them to recommend additional research approaches to help us clarify our understanding of these mechanisms. When we receive their recommendations we will incorporate them in our research plans. In addition, our current research plans, including the National Lake Survey, the terrestrial survey, and the long-term watershed studies, should provide us with the tools needed to determine where our affected watersheds lie on the continuum of possible responses to acid deposition.

The Federal Interagency National Acid Precipitation Assessment Program will concentrate on three areas to improve our understanding of source/receptor relationships. First, we will conduct field tracer studies to obtain a better understanding of the complex meteorology of long distance pollutant transport. Second, we will seek to better characterize the complicated sequence of chemical reactions which make up the transformation process. (That is the process by which sulfates, nitrates, oxidants, and other pollutants are formed in the atmosphere.) Finally, we will incorporate this improved understanding of meteorology and chemistry into more sophisticated atmospheric models so that we can analyze and predict the effectiveness of alternative control strategies.

Concurrently, we will use this time to work with the states on the complex implementation problems that any acid rain control program would pose.

Now let me turn to two areas that have only recently assumed more importance in the acid rain debate, and which have received considerable attention before this Subcommittee. These are damage to forests and damage to health.

Based on a limited amount of data, it appears that over a wide area of the Eastern United States, there has been a pronounced decline in tree diameter growth of several species of trees over the past two decades. This lack of growth is not correlated with any specific climatic trend, and because it involves a number of species over such a wide geographical range, it does not appear to be solely attributable to normal ecological processes.

In high altitudes, a more severe set of symptoms called die-back has been observed. We have seen significant losses in at least five species of trees.

In Europe, different and more extensive types of tree damage have been observed, involving at least ten species.

We do not know the true extent or meaning of this damage, the speed at which it is taking place, or what factor or combination of factors is causing it. We do not know if the causes are the same in Europe as in this country. Many investigators believe that several interconnected factors are at work, and that air pollution of some sort may be important among them. Our current knowledge, however, does not tell us whether the offending pollutants are sulfates, nitrates, oxidants, or heavy metals. This new information, while troubling, raises the possibility that if we act too quickly, we may control the wrong pollutant.

This situation illustrates well why waiting for further research to be completed before initiating a control program is a rational decision. If, as many believe, sulfate deposition is not a major contributor to forest problems but oxidants or nitrates are, a significant reduction in SO_2 emissions could inadvertantly result in elevated levels of oxidants or nitrates. Our current understanding of atmospheric chemistry indicates that if we were to reduce SO_2, it might result in increased levels of oxidants. Additionally, excess oxidant could then combine with the NO_x to produce more nitrates. Thus, in either case controlling the wrong pollutant could conceivably make matters worse.

The interagency research program expands the work on forests. A long-term terrestrial survey is being designed and should be ready to be carried out in about a year. EPA is sponsoring joint meetings and field observations by European and American scientists both here and in Europe to identify the major hypotheses which could explain the mechanisms of forest damage. Once these hypotheses are identified, research efforts can be launched to test them either in the field or in the laboratory in order to identify the proper cause and effect mechanisms.

Some witnesses have testified before this Committee that acid rain causes health damage. We agree with the recent National Institute of Environmental Health Sciences report on this subject which, though cautious, did not find any basis for immediate alarm. Nevertheless, as the Institute suggests, further assessment is warranted to expand our understanding of such potential effects as the leaching of heavy metals into drinking water by acid rain, and the impacts of breathing sulfates and acid fog.

When I testified on acid rain before the Senate Public Works Committee last month I was repeatedly asked when we will know enough to make a decision regarding controls. I am sure that many of you have the same question. The answer is that I do not know, because I cannot predict ahead of time what answers will come out of our research program or when.

The Interagency Task Force plans to produce formal assessments of the information gained from the acid deposition research program in 1985, 1987, and 1989. These will be important milestones in integrating our understanding of acid rain's causes and its effects. However, our assessment of the policy impact of what we are learning from the research program must be a continuous process. As we continue to gain knowledge of the deposition problem, our ability to predict the results of various control efforts will increase, and we will reach the point where the Administration can responsibly make a decision regarding the need for additional controls. I cannot tell you exactly when that point will come, for I cannot predict what the answers from the research program will be or when they will be forthcoming. What I can tell you is that I take it as an affirmative duty on my part as Administrator of EPA to ensure that we make this active reassessment an ongoing process and that I communicate our newly-found knowledge to the key decision-makers in the Administration, including the President, as soon as appropriate.

This concludes my summary of acid rain. I recognize that this issue has been and remains a most divisive one between many members of Congress and the Administration. Unlike any other pollution problem, acid rain has the potential for dividing us along regional and international lines. I believe that if we all approach this problem with good will and a recognition of the legitimate concerns of people in every section of this country and Canada, we can solve it. I pledge my best efforts to work with you to do so.

Let me turn now to the question of our regulation of hazardous air pollutants under section 112 of the Clean Air Act.

It is no secret that EPA has had problems in implementing section 112. While some of these have been the result of management problems which we are working hard to correct, others are the inevitable result of the complex nature of the problem and the scientific uncertainties involved. Given the difficulties we have had in implementing section 112 -- difficulties that have extended over many years and several Administrations -- it seems reasonable now to take a hard look at the structure of the hazardous air pollution program.

Section 112 requires EPA to impose numerical emission limits on industrial sources of a specific chemical that EPA has "listed" on health risk grounds. Cancer is the health risk at issue in virtually all listing decisions.

Our knowledge about the cancer-causing effects of exposure to various substances at ambient levels is far from perfect. To best protect public health, given this uncertainty, EPA has evaluated the cancer risk of chemicals by making conservative assumptions that yield a plausible upper-bound estimate of the risks at low doses. For example, we assume that the cancer risk of exposure to a chemical does not vanish to zero as the dose declines, but decreases in a linear fashion with the dose level. We also assume that a substance acts as a carcinogen in humans with the same potency that it shows in the most sensitive laboratory animal species. We base our exposure estimates on dispersion modeling, and in some cases we assume that people spend their entire lives out-of-doors breathing ambient levels of these pollutants. Given these assumptions, we are confident that our risk estimates for individual chemicals are probably overestimates of risk. That is, the chances are high that the true risk falls below our estimates. In some cases, that risk could be as low as zero.

Using these conservative assumptions, we have assessed the cancer risk from emissions of these pollutants from industrial point sources such as chemical and manufacturing plants. In many cases, these risk assessments indicate that the health benefits of requiring controls on most industrial source categories are relatively low. Based on our current experience, NESHAP standards that eliminate more than one cancer case per year are more the exception than the rule.

Such tentative findings are disturbing because they suggest that the current approach to regulating air toxics may not yield much in the way of public health protection. Indeed, our current information suggests that most hazardous air emissions arise not from major industrial sources, but from numerous small sources and from "non-traditional" sources such as waste dumps. In those cases where the culprit is a large industrial source, we often find that there are only a few others like it across the country. We are now engaged in a serious attempt to estimate the public health risks from such sources and to compare these risks with those associated with the major industrial sources traditionally addressed under section 112.

This is not to say that preventing these relatively few cancer cases which may be caused by hazardous air pollutants from industrial sources is not important. Obviously, it is. But we all have a responsibility to use the limited resources of government and society to locate and reduce the most significant risks first. In these cases, it appears that the limited resources used to set NESHAPs may be employed elsewhere to achieve greater public health protection.

Given what we know about the nature of cancer and the hazardous air pollutant problem, we think the Congress should adjust the Act so as to have its terms confront reality.

The current statutory language requires the Administrator to "list" any air pollutant which he intends to regulate and which he finds "may reasonably be anticipated to result in an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness." After listing a pollutant, the Administrator has one year to establish a national uniform "emission standard" for each type of source of the pollutant that is strict enough to "protect the public health" with an "ample margin of safety." Typically, there are at least a half dozen types of sources of a single pollutant--meaning that to list 10 pollutants in a year triggers a requirement to make at least 60 regulatory decisions the next. Furthermore, in some cases our assessment of source categories suggests that the public health risk is so small as not to warrant controls. The statute does not mention any factors other than health and safety that the Administrator is allowed to consider in making those regulatory decisions. It is not possible, without banning a substance, to establish "safe" levels for carcinogens, if by "safe" we mean entirely free from risk.

The current statutory language can thus be read to require us to eliminate all risk from chemicals we list regardless of cost or social impact. Often the only way to eliminate risks would be to ban production and use of the chemical.

In implementing section 112, we have taken it as given that Congress did not intend us to eliminate these chemicals. We have made judgments about safety, and have attempted to balance many factors, including the nature of the risk and the cost of eliminating or minimizing it. In my judgment, the varied circumstances we face in this area make the authority to engage in such balancing efforts all the more imperative.

If we are correct in this assessment, then Congress should move to make such balancing explicit in the language of the Act. If we are meant to act against chemicals for which we cannot establish a risk-free level without banning their use in every case, the statute should clearly say so and tell us what factors to weigh in stopping short of a ban.

Any such test should certainly recognize the high value the American people place on public health and should assign it great weight in any balance that is struck. But the law should also recognize that the balance itself is necessary whatever weight a particular factor may be given.

Increased flexibility to treat the varied nature of toxic air pollutants, exercised pursuant to Congressionally established criteria, would render the job of the Administrator of EPA possible and would make the goals of section 112 attainable.

I understand Congress' impatience with the rate at which EPA has acted under section 112. As I testified before Chairman Dingell last fall, we are committed to working through most of our present backlog in the next few years. By doing this we will have examined and acted upon the health risks that may be posed by chemicals now being considered for listing. I believe that statutory amendments such as I have described that recognize the reality of the problems we face would help us in that task. Any such amendments must be based on an appreciation of the complex and varied nature of the problem of toxic air pollutants, not simply on a conclusion that everything must be done faster because too little has happened in the past.

Finally, let me say a word about the process of setting ambient air quality standards, and the use of statutory deadlines for achieving them.

Since I returned to EPA a year ago, I have repeatedly stressed the importance of separating risk assessment from risk management. The process of setting ambient air quality standards and then requiring the use of deadlines to force their attainment illustrates this point. Under present law, setting standards is based solely on my determination of what is needed to protect public health or welfare. I have no quarrel with this approach as it is solely a risk assessment exercise.

However, here is where the problem starts. Once set, the standards must be attained by fixed deadlines. It is in this risk management phase that I believe the Administrator should be given more flexibility. Nowhere does the statute explicitly provide for consideration of the economic or other impacts of attaining a given standard by a set deadline. Indeed, the statute can be read as saying that if the deadlines are missed, sanctions are automatically imposed. Prudent public policy demands that those charged with seeing that a goal is achieved be given the discretion to evaluate relevant factors. Historically, the statute has been _read_ to provide this necessary flexibility. The law should _explicitly provide_ it.

Congress has recognized the problems with these deadlines in the past by extending them. The problem is not with the particular dates chosen, however, but with the inflexible nature of the approach. We are not repudiating the concept of deadlines. Indeed, even though many areas of the country are in the post-deadline period right now for some pollutants, our policy continues to make use of deadlines for most of these areas. But in some areas deadlines are simply unattainable. The Los Angeles region, for example, is clearly not going to be able to meet the 1987 ozone standard. In those areas, we have required states to adopt specific measures leading towards attainment of the standards rather than meet impossible deadlines. For that type of situation, we think it is appropriate to expect very strict but realistic and enforceable measures as a _quid pro quo_ for extension of the deadline. The existence of a deadline that cannot realistically be met places us in the posture of being unable to act reasonably with an area that has done everything it knows how to do to meet the standards. This undermines the integrity of the law and tends to freeze people in place. We want to ensure real movement towards the standards, and we would recommend that a more flexible approach be adopted in achieving them.

I would be happy to answer any questions you may have.

The Chairman. Thank you very much, Mr. Ruckelshaus. Secretary Hodel.

STATEMENT OF HON. DONALD PAUL HODEL, SECRETARY, DEPARTMENT OF ENERGY; ACCOMPANIED BY JAN MARES, ASSISTANT SECRETARY, POLICY, SAFETY, AND ENVIRONMENT

Mr. Hodel. Thank you, Mr. Chairman.

I, too, have a statement which I would like to submit, if I may, for the record.

The Chairman. It will be included in the record.

Mr. Hodel. I am accompanied this morning by Assistant Secretary Jan Mares, who is the Assistant Secretary of the Department of Energy for Policy, Safety, and Environment. He and his staff have devoted considerable effort to analyzing the consequences and causes of what is called acid rain.

The context in which I appear here today, Mr. Chairman, is within the context of the National Energy Policy Plan, which I have talked about before this committee on several occasions.

Our goal of an adequate supply of energy at reasonable costs is one which has received an agreeable response, but I must emphasize that when we look at the words "adequate" and "reliable" it brings me to the point today of testifying.

I do not assert that I'm an expert on acid rain, Mr. Chairman, but I have had to concern myself with it, as Secretary of Energy, when I look at the potential consequences to the energy supply system of this country. Obviously, there's a debate, which all of the witnesses today and members of this committee have commented on, on a wide range of issues.

Certainly, reasonable people can differ as to the status of the facts, but it appears there's a debate over the scope of the problem, the pace at which it is proceeding, the change in current levels of damage, and the sources of any particular given consequences in any particular area or region of the country.

There is also a debate on cost, certainly on the levels of cost. But there is not a debate on whether the proposals that are before this committee will have a costly impact on consumers. Either as ratepayers or as taxpayers, they will pay a significant amount of money for the options that are under consideration.

Our view is that this is certainly appropriate, if there are benefits which are being purchased by the consumer for those hard-earned dollars. But, we believe that the trends from the studies that have been reviewed today and talked about on many occasions, indicate that in fact we're on the right track as far as these emissions are concerned.

In the early 1970's, electric utility generation projections showed a rapid and continuing climb in the number of electric powerplants that were going to be built in this country.

There was a corollary, rapid projection of acid emissions rising, in parallel with the number of plants. But in the mid 1970's, in fact, we got off those trend lines, both on the number of plants and on the acid emission aspects.

Now, in fact, the charts which are attached to my testimony indicate that the trend line is downward. We have, in fact, reduced the amount of acid emissions far below what had been anticipated by this stage of the 1980's.

Last year's estimate, Mr. Chairman, which is the second chart attached to my testimony, began at 2 to 3 million tons per year higher than the actual trend lines that we now are dealing with.

What we don't know—and certainly this is all at the projection stage, dependent upon a host of utility and energy activities, not particularly under the control of anyone these days—is how long this downtrend will continue and how deep it will be.

The EPA estimates indicate that they expect some stabilizing of the output for a period of time toward the end of this century, at which time, with new plants, with new control technologies on them, the acid emissions would decline.

But, in fact, I must emphasize, that we began this year at a lower point in acid emissions than we had expected to achieve by 1998 under the more favorable trend lines.

So we have certainly been on the right track.

Now, there are consumer energy consequences to any proposal which increases the cost of energy to the consumer.

The electric costs could range—and it depends on whose estimates you use—but the estimates range from $3 to $7 billion per year, either as ratepayers or as taxpayers.

The capital costs in nominal dollars may be as much as $40 billion for some of the proposals. That may be the high side. But if you cut that in half, it's still a $20 billion burden on the consumers of America.

In the coal markets, we're concerned about the lost employment opportunities for miners, about taxes, about lost revenues in some of those areas. It would increase the pressure to import energy to the United States if we unduly, unnecessarily raise the price of energy in this country.

There are some proposals that would take lower-cost existing powerplants out of service sooner. If that is through curtailment, or if it's retirement before their time, there is a direct cost consequence again to the consumer.

I think in summary, Mr. Chairman, that it's clear from an energy standpoint, if one looks at this debate, that there is a considerable amount of uncertainty about the causes, the effects and the cures. There's also uncertainty, but no doubt there will be a cost to the consumer, and that cost will be in many billions of dollars.

The question we can't answer is: Is that a low- or high-cost compared to the benefits that might be retained? The value of the benefits are uncertain today. Under the proposals that we have undertaken and this committee has discussed, the President's program, we are seeking aggressively to determine what the answers are to those questions of uncertainty.

We do not deny that acid rain may be a problem to this country. We think it is being dealt with by the present law, and we do have time, because of the beneficial trend lines, to know more about the problem before we choose the course that we must take to resolve the problem further.

Thank you.

[The prepared statement of Mr. Hodel follows:]

STATEMENT OF DONALD PAUL HODEL, SECRETARY, U.S. DEPARTMENT OF ENERGY

Good morning Mr. Chairman and Members of the Committee. You have invited me to present testimony concerning issues relating to the acid rain phenomenon. I emphasize at the outset that this testimony is oriented toward the reasons why the Administration cannot support any emission rollback proposals at this time.

Before I proceed to present my views as set forth above, I want to talk briefly about the President's National Energy Policy Plan. I do this because proposed legislation regarding rollback will impact negatively on that Plan. The National Energy Policy Plan (NEPP IV) sets forth a clear statement of policy on energy for the country. The goal is to provide an adequate supply of energy at reasonable costs. Our strategies for achieving our energy policy goal are two-fold: 1) minimize federal intervention and control of the market place, consistent with requiring adequate health, safety and environmental protection, and 2) promote a balanced and mixed energy resource system that includes a full range of energy technologies which compete fairly in the free market. Obviously the issue of acid rain is directly relevant to both of these strategies as well as our overall energy policy goal.

Let's turn now to the issue at hand.

When considering appropriate actions in response to apparent problems we must not only concern ourselves with the effects on materials, vegetation, aquatic life, etc. we must also give attention to the impact on real people. How will our actions affect their lives, their jobs, their pocketbooks? We need to be as certain as we can reasonably be that the benefits derived from our actions justify the burden we place on those affected.

Reduction of SO_2 emissions by 10-12 million tons per year, relative to the 27 million tons emitted in 1980, would be an expensive and disruptive new program of questionable necessity and uncertain benefit. EPA Administrator Ruckelshaus has aptly described, on several occasions, the numerous uncertainties concerning the linkages between acid rain causes and effects and potential future trends. I fully agree with the Administrator that there is currently insufficient evidence and understanding to warrant a massive national program of additional SO_2 control.

I am particularly impressed by the available information on emission and adverse effects trends. The historical trends in SO_2 emissions, based on a recent EPA publication, are shown in Figure 1. Note that the rapid historical increase in SO_2 emissions -- especially from electric utilities -- has been halted and reversed since the Clean Air Act Amendments of 1970. For example, actual 1982 SO_2 emissions were some 25% less than in their peak level in 1973. Furthermore, these 1982 emission levels are over 40% less than they would have been had emission control remained at 1970 levels and all other factors continued as they actually did over this period.

Future trends in SO_2 emissions are uncertain due to questions about sucn factors as economic growth, utility boiler life expectancy and New Source Performance Standards stringency. The medians of the range of projections indicate approximately constant emissions in the near term and declining emissions in the long term as existing plants retire and are replaced with new plants meeting stringent emission limits. Several projections of future trends are shown in Figure 2.

Trends in surface water acidity, recently described in publications of the U.S. Geological Survey, indicate a slow improving trend in the Northeast -- the area where over 200 acidified lakes have been identified. This observation is consistent with the declining trend in SO_2 emissions and with the "rapid response" relationship between emissions and surface water acidity.

When all these trend indications are combined, the possibility emerges that the growth in the acidification of surface waters in the northeastern U.S. has been halted and reversed following passage of the Clean Air Act, and that any remaining long term risks will be further reduced by the long term effect of the current Act's New Source Performance Standards provisions.

Let me hasten to underline the word "possibility." The current data are sparse and our understanding is not conclusive. Corroborating findings from the Administration's accelerated research program as well as the substantial private sector research efforts will be necessary to determine with confidence which, if any, additional acid rain control measures are appropriate. My point is that current uncertainties over responses to the "acid rain issue" prominently include the possibility that the current Clean Air Act may well be sufficient -- hardly circumstances supporting a major new program to reduce SO_2 emissions by an additional 10-12 million tons per year.

The foregoing impressions have emerged from Administrator Ruckelshaus' several public statements and from my own staff's analyses which corroborate those statements. My own expertise is energy, not environmental protection, so I will defer to the Administrator on the numerous technical nuances of the complex acid rain phenomenon. There is, however, no question that the several Senate proposals would substantially affect energy costs and fuel choices.

The general energy impacts of bills requiring major rollbacks (10-12 million tons) in sulfur emissions are substantial. Specifically:

- It has been estimated that electricity costs under such bills could be 3 to 5 billion dollars[1] per year higher depending upon the assumptions made concerning method of control, fuel costs, and many other key economic factors.

- Under some proposals the electric power industry would be required to undertake as much as 40 billion dollars[2] of additional capital financing (measured in nominal dollars).

- There could be major shifts in coal markets, which would result in significant miner dislocation.

- There would be upward pressure on energy imports, particularly electricity, potentially increasing the balance of payments problem.

- Many existing, low cost coal-fired power plants would experience curtailed operation or retirement well in advance of physical obsolescence since scrubber retrofit could prove to be economically unacceptable.[3]

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[1] Measured in levelized, constant dollars; when measured in levelized nominal dollars this range can go as high as 8 billion dollars per year.

[2] (nominal dollars; over $20 billion when measured in constant 1985 dollars). Temple, Barker & Sloane, "Evaluation of H.R. 3400..." September 20, 1983.

[3] Temple, Barker and Sloane estimates this impact as effective 19 GW of capacity.

Although some of these impacts are more significant than others, in sum, the cost of major rollback legislation is both significant and real. This underscores the importance of assuring that the benefits are commensurate.

The impacts of rollback bills on the financial condition of the electric utility industry are substantial and deserve consideration. As I noted earlier estimates of the capital requirements of some bills have ranged as high as 40 billion dollars. The burden to reduce emission, and associate capital costs, would fall on the customers of a relatively small number of utility companies (10 companies will shoulder about 45% of the emission reduction burden.) And the need to generate capital for the needed control equipment would be imposed on an industry that is already beset with difficult financial problems. It is certainly easy to understand why the industry objects to the prospect of these large capital requirements, even if a portion of these may be offset by later national fee collections.

All the various modelling efforts evaluating the impacts of these bills agree that there will be noticeable residential and industrial rate impacts resulting from the proposed legislation. Electricity cost impacts have been estimated to range as high as $115 annually per household on some utility systems. In eight states residential electricity costs are estimated to increase by 10% or more, with Missouri and Indiana experiencing increases in excess of 20%.[4] Industrial rates would be proportionally impacted. For example the TBS analysis projects that industrial rates in eleven states will go up by more than 10%, with four states (Missouri, Indiana, Kentucky and Ohio) experiencing increases in excess of 20%.[5] These added environmental costs reduce industrial competitiveness to some extent, which in turn translates for some into reduced economic growth, lost jobs, and lost tax revenues.

Because of its relevancy in any discussion in control strategies, we are preparing information concerning the cost of scrubbers, reliability of scrubbers, the time it takes to plan and install them, their operation and maintenance costs, and other pertinent information which will be forthcoming in our subsequent submittal to the Committee. Suffice it to say in summary that the experience to date shows that scrubbers do work. They are effective tools in reducing sulfur emission; however, these gains are obtained at the expense of substantial capital costs (e.g. estimates range as high as $400/kw) and significant operating penalties (e.g. estimated at a 7-10% reduction in plant efficiency due to control power needs and reliability loss).

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4. Temple, Barker & Sloane, "Expanded Executive Summary to Evaluation of H.R. 3400..." January, 1984. .

5. Temple, Barker & Sloane, "Expanded Executive Summary to Evaluation of H.R. 3400..." January, 1984.

As you know the Department is involved with major efforts to develop alternative technologies for SO_2 emission reductions. The FY 1985 budget includes $57.5 million for R&D on technologies that could be employed to reduce sulfur dioxide emissions. Five million of this total would be specifically earmarked for developing better retrofit systems and eleven million for advanced coal preparation processes which might eliminate the need for retrofitted scrubbers. The remaining funds support research on a wide range of alternative technologies which can reduce sulfur dioxide emissions, including fluidized bed combustion, coal liquids mixtures, and others. These R&D efforts hold the promise of substantially reducing the future cost of sulfur removal in existing facilities.

From an energy viewpoint a major concern is the impact of these proposed bills on both the high and low sulfur coal industries. On this point there is substantial variance from bill to bill. For example some bills, which mandate that power plants install scrubbers, would probably have a minimal impact on high sulfur coal markets. Legislation which offers the utility companies a free choice on how to reduce emissions would increase likely shifts to low sulfur coal. The freedom to choose a control method, while producing the most economically efficient outcome, would also cause the most severe dislocations in high sulfur coal markets and coal miner employment.

In the context of the acid rain deliberations, some have asked about increasing dependency of many states, particularly the Northeast, on electric power exports from Canada and the impact of these exports on the U.S. coal industry.

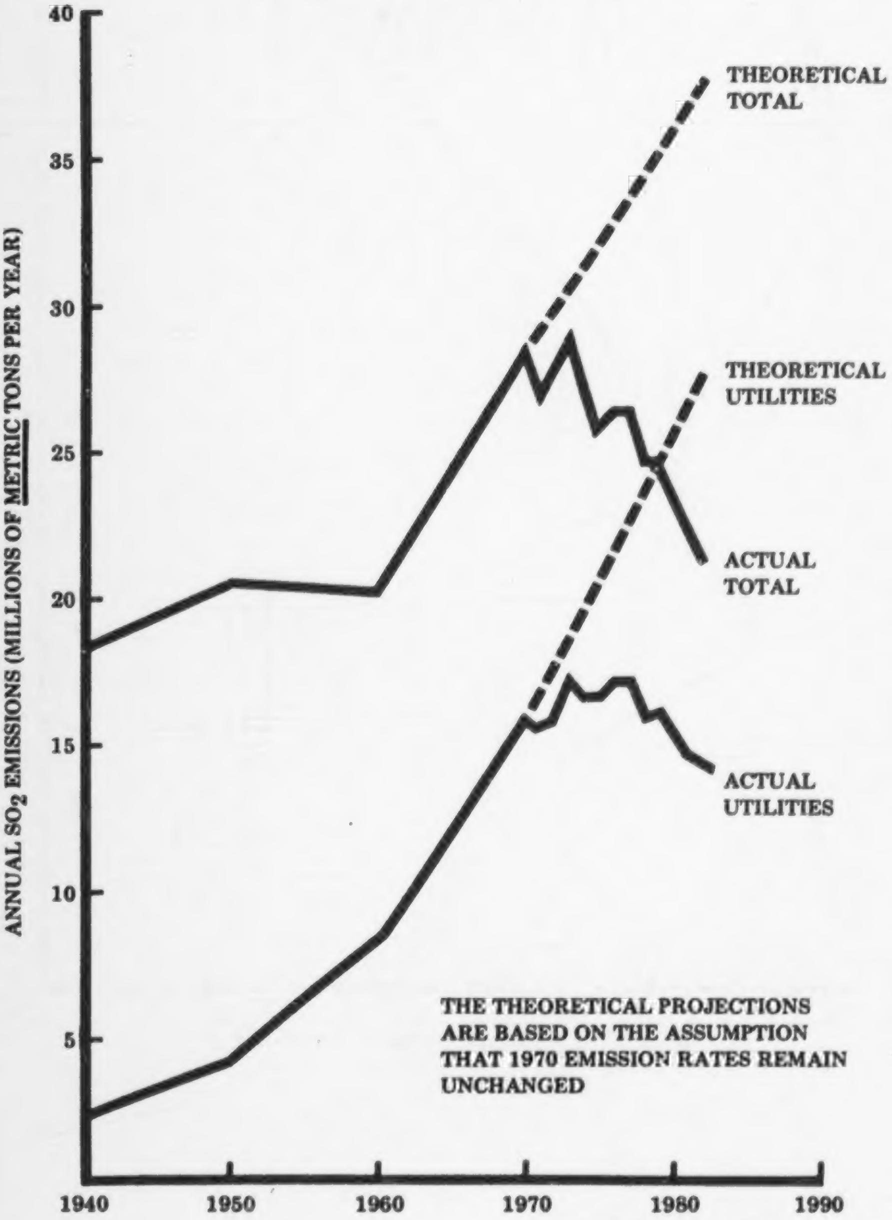
Any factor which serves to increase the cost of electricity produced in the U.S. or which constrains the use of existing domestic electricity generating resources could serve to expand the amount of Canadian electricity imports. Since we have already shown that massive acid rain rollback programs will probably do both, then we can assume that such programs could lead to more electricity imports. Furthermore, if the cost of energy derived from our domestic resources rises substantially, imports of energy or non-energy products may also rise.

Total electricity imports from Canada in 1982 were 34,000 gigawatt hours. This is roughly equivalent to the output of twelve 500 megawatt coal-fired power plants operating at a 65% plant factor. Based on existing contracts and future contracts we know to be under consideration today, this level of imports could approximately double by 1990. Beyond 1990 the uncertainties in projecting this number are great. A study by the Canadian Energy Research Institute estimated a total market potential (not a projection of actual sales) of 500,000-1,000,000 gigawatt hours/year, between 15 and 30 times greater than current levels of import. Obviously, the more energy we import to meet our needs the less we produce ourselves, with the attendant impacts on our domestic energy producing sectors.

There is nothing inherently wrong with expanding the level of electricity imports. In the past, such power sales and exchanges have offered substantial benefits to both countries. However, we must be wary of any circumstance which causes us to develop an undue reliance on any single foreign source of energy. Past experience has yielded a clear message that undue dependence on foreign sources translates quickly into reduced control of our collective energy and economic fates. Such dependence also invites high prices for the foreign commodity. Our environmental policies must be sensitive to these important second-order effects.

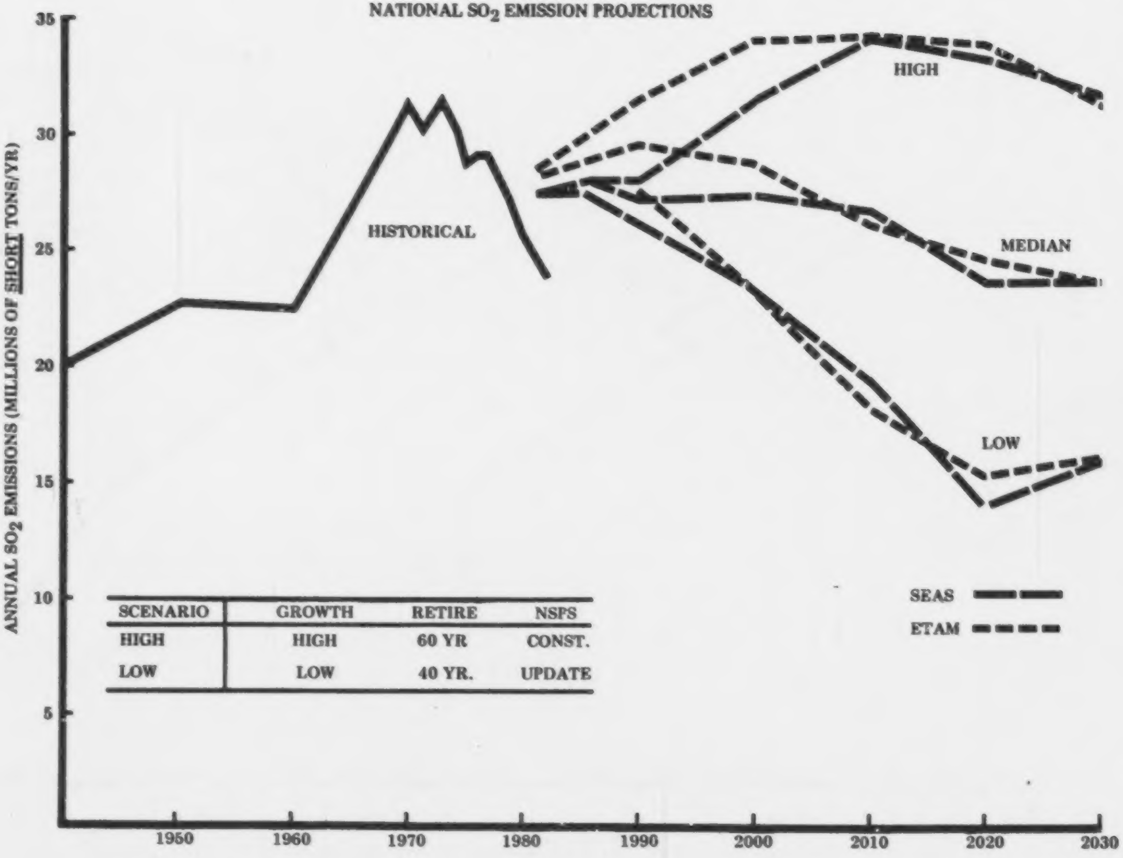
I would again like to emphasize that the Department will be providing more detailed information soon. I hope these brief summary responses are of value in the meantime. In conclusion, Mr. Chairman, I believe that the 10-12 million tons per year SO_2 rollback proposals are of questionable necessity and uncertain benefits. In contrast, I am quite certain that such measures would be expensive, have severe impacts on the energy policy of this country and would move us away from a balanced approach to meeting our energy needs. Unless and until we receive information that would resolve some of these uncertainties in a way that would provide a sound basis for supporting additional measures, I believe accelerated research along the lines of the President's budget request is a scientifically supportable and appropriate course of action for the present.

FIGURE 1
NATIONAL HISTORICAL SO_2 EMISSIONS



SOURCE: EPA-450/4-83-024
FEB. 1984

FIGURE 2
NATIONAL SO_2 EMISSION PROJECTIONS



SCENARIO	GROWTH	RETIRE	NSPS
HIGH	HIGH	60 YR	CONST.
LOW	LOW	40 YR.	UPDATE

The **Chairman.** Thank you, Secretary Hodel.

Mr. Alan Hill.

Mr. **Hill.** I have a statement on file, and would ask that to be made a part of the record.

The **Chairman.** Mr. Hill, that will be made a part of the record.

Mr. **Hill.** Thank you.

STATEMENT OF HON. A. ALAN HILL, CHAIRMAN, COUNCIL ON ENVIRONMENTAL QUALITY, EXECUTIVE OFFICE OF THE PRESIDENT

Mr. **Hill.** Let me just briefly review my statement, which goes to the role of the Council on Environmental Quality with regard to the task force which oversees the research program.

I'm very pleased that attention is being paid to this program, because it is a comprehensive one. The national research plan has been prepared in an open, participatory manner. The results have been made available on an annual basis. The next report will be available early this summer.

Dr. Bernabo is on your next panel. Dr. Bernabo is the executive director of the assessment program and can give you specific details with regard to the work of the panel.

It's a pleasure to be with you. I'm available for questions.

[The pepared statement of Mr. Hill follows:]

STATEMENT OF A. ALAN HILL, CHAIRMAN
COUNCIL ON ENVIRONMENTAL QUALITY
BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

April 30, 1984

Good morning. I want to express my thanks to the Committee for extending an opportunity to me to participate in this oversight hearing. Members of the Interagency Task Force on Acid Precipitation are familiar with my concern that few in our society are aware of the comprehensive research program currently underway. It is important work and will form the basis for informed decision-making. Dr. Chris Bernabo, Executive Director of the National Acid Precipitation Assessment Program will be testifying later today and will give you more detail. I would, though, underline the fact that our Administration is serious about developing adequate scientific information before implementing further controls for emissions of sulphur dioxide and oxides of nitrogen.

CEQ has a unique role on the Task Force. It is the only agency that is not directly involved in actual research. The Council has been designated as Executive Secretary of the Task Force and has been given the responsibility to directly manage and supervise the activities of the Task Force and its staff (copy attached). We have received very good cooperation from the Task Force's member agencies.

In exercising our role as Executive Secretary, the Council has been careful to deal with management issues and to avoid possibile claims that policy makers have politicized the research or in any way influenced the results of the scientific work. We feel the Council's role is one to see that adequate attention is given by policy makers in each of the participating agencies and that the results of the research are obtained in a timely manner.

We view the acid precipitation issue as a serious one. Since the 1930s, some lakes have become acidified and rainfall does appear to have a lower pH than historical samples would suggest; however, present data are sparse and a direct cause and effect relationship between acid precipitation and adverse effects has not been determined. However, with the present state of scientific knowledge, the Administration is not prepared to recommend additional controls. Other witnesses will present information regarding current research activities.

EPA Administrator William Ruckelshaus put it best last February when he testified, "That does not mean the door is closed. It simply means that before launching the country on an expensive and potentially divisive control program, we feel we need more scientific information."

In 1979, Senator Moynihan, when discussing the proposed Task Force, gave us the guide for action. He said, "It will be possible to make profoundly gross mistakes here if we do not do some research first, mistakes that would cost billions.... This is work for good brains, given a certain amount of resources and a certain amount of time."

Our Administration wants to avoid mistakes. At the same time we recognize that the problem is serious. The President has proposed a careful course of action. He has asked:

- o First, to double the appropriation for the research effort. If the budget request is approved, we will have reached a total investment of more than 125 million dollars since 1982.
- o Next, a request for a program to help restore the buffering capacity in affected lakes. This program will involve the states in affected areas.
- o Finally, 67 million dollars has been requested for research and development on new technology in coal combustion.

This three-part effort provides a comprehensive program for responding to the acid precipitation problem and is what is needed to acquire additional scientific knowledge. As further knowledge is developed, it will enter into the decision-making process. In the meantime, the Task Force's program will continue to operate and will continue to report its achievements on an annual basis. The 1983 report will be published in early summer and I will make sure the Committee is provided with copies.

Again, please accept my thanks for your invitation to participate. I'm available to answer any questions.

THE WHITE HOUSE
WASHINGTON

January 31, 1983

MEMORANDUM FOR DEPARTMENT AND AGENCY HEADS

FROM: EDWIN MEESE III
COUNSELLOR TO THE PRESIDENT

SUBJECT: ACID RAIN POLICY COORDINATION

Acid Precipitation is a major environmental issue for this Administration, both domestically and internationally. There are a number of federal departments and agencies currently involved in acid precipitation activities, and the need for overall policy coordination is growing, especially with respect to the Acid Precipitation Task Force.

Therefore, I am directing that the President's Council on Environmental Quality serve as the lead coordinating agency for acid precipitation. CEQ was designated as Executive Secretary in 1980. This reiterates existing policy. CEQ, with the statutory responsibility to provide policy guidance on major environmental issues, and as the only member of the Task Force not directly involved in research, is well suited to carry out this function.

Thus,

- CEQ is designated as the Executive Secretary of the Acid Precipitation Task Force with responsibility to directly manage and supervise the activities of the Task Force and its staff.

- CEQ is further directed to provide overall policy coordination on this issue for the Administration.

- All Departments and agencies involved in the acid rain issue are directed to cooperate with CEQ and to provide assistance when requested.

These instructions will not interfere with the statutory responsibilities being carried out by the various departments and agencies.

The CHAIRMAN. Thank you very much.

Before beginning the questioning, I might note for members of the committee, that Secretary Hodel has a time constraint and will necessarily leave in about 20, 25 minutes. However, Secretary Mares will remain to answer questions that might be addressed to the Department of Energy.

We will operate on the first round on the usual time constraints. Senator Johnston.

Senator JOHNSTON. Thank you, Mr. Chairman.

Did you say you wanted us to first ask Mr. Hodel the questions directed to him?

The CHAIRMAN. If you have questions of him as distinguished from Secretary Mares. He has less time to address questions.

Senator JOHNSTON. OK. Mr. Hodel, I note that the administration has requested $67 million in fiscal year 1985 for control technology research.

It seems to me that combustion technology offers a very rich field for research, but figure of $67 million seems to be such a modest sum, relatively speaking. And I know that expenditures are being made in other fields, in basic sciences and fusion and other things which in my view, are less immediate but much more costly.

I wonder whether $67 million is sufficient for combustion technology considering its importance, and future promise.

Mr. HODEL. Senator, as you know, we have this discussion with the various committees of Congress as we present our budget.

In areas such as fusion, we are very much at the frontier of science in areas that have severe technological problems, as you and I have discussed in a prior hearing.

In the case of the burning of coal, there is a great deal of knowledge about coal, about its chemistry, about the burning of it, how to clean it. What we're doing is working, really, at the research margins, if you will.

We are pursuing areas that we hope have promise to find ways either of cleaning the coal before we burn it, burning it cleanly, such as the atmospheric pressurized fluidized bed processes, or by cleaning the stack gases before they are emitted.

So we're focusing our attention on the three major areas, and we think it is a responsible program that has a pretty substantial expenditure when you consider the levels of unknowns that we're dealing with.

But it is not an area that one can say absolutely freely there's no doubt that everything that can be researched responsibly is being researched, but we have substantially increased our requests, and the committees have seen fit to meet those requests.

Senator JOHNSTON. I understand that at the hearing on Senator Byrd's coal technology bill, S.1659, of which I am a cosponsor, you indicated that an additional $100 million might be available for coal technology research.

Would you care to elaborate on that?

Mr. HODEL. Senator, I believe that was the testimony of Assistant Secretary Vaughan, who is the Assistant Secretary for Fossil Energy. And I do not personally have a specific awareness of what he might have been referring to.

He may well have been indicating that we continue to look at opportunities for research, and he may well have as much as $100 million of projects which he's looking at as possible additional areas for expenditure.

Senator **Johnston**. Thank you, Mr. Secretary.

Mr. Ruckelshaus, would you point out to us what you feel are some of the potential problems with the Mitchell bill?

Mr. **Ruckelshaus**. Your assumption is, at this point, quite a leap, Senator Johnston. The problems, I think, are the kinds that will be raised by those who are being asked to pay the bill; the very ones that were raised by the minority leader when he testified about the cost of this.

There are problems raised in how that cost is distributed. Under his bill it is distributed primarily on the ratepayers of the affected utilities in the middle west, and the high-sulfur content coal miners. That is basically who would pay the cost of this under his approach.

The objections to that approach are the ones you might expect to be raised by the people who would bear the brunt.

Senator **Johnston**. How would you improve the coal allocation formula?

Mr. **Ruckelshaus**. Well obviously, if the Congress decided to go forward with some kind of control program—I don't quarrel with Senator Mitchell's description of where he thought—he hoped I would support him in terms of letting the States decide through the State implementation plan process how they would distribute the required reductions that the Congress might impose on them on a cost-effective basis. I think that should be done.

Realistically, if it were going to stand a chance, I believe, of passing the Congress, there has to be some way of distributing these costs on a basis that doesn't load it all on those otherwise economically distressed areas of the country that now are somewhat more skeptical than the Northeast, for instance, about the benefits associated with sulfur oxide control.

Senator **Johnston**. Well, specifically how would you do that?

Mr. **Ruckelshaus**. There are a number of ways of doing it. You could do it through a general taxpayer base. You could do it through a tax on the generation of electricity, excluding certain forms of electricity, like nuclear or hydro, that had been suggested. You could do it in emission tax. As much imagination as there is in this Congress, there are ways of doing it.

Senator **Johnston**. Do you think an emissions tax would be preferable, if the Congress decided to pass legislation this year?

Mr. **Ruckelshaus**. You know, again, I'm not backing away from the statement I made here in terms of what's advisable. I guess my sense of it is that as a practical matter, if a bill of this kind were to stand a chance of passing this year, or in subsequent years, for controlling SO_2, there has to be found some way of distributing those costs, for the people in that part of the country that would bear the full brunt of the cost are going to resist very strongly through their elected Representatives in the Congress.

Senator **Johnston**. Mr. Ruckelshaus, one of the shortcomings of this bill, according to some, is the fact that it provides so little flexibilty; that is, it mandates a reduction, which tilts in favor of washing and stack-cleaning as opposed to combustion technology.

Since clean combustion technology is not currently available, and it's one of those methods that we hope with research will become available in the future, the bill, in effect tilts against its use by requiring that emitters take the action now in coal washing and stack cleaning.

Would you comment on that?

Mr. RUCKELSHAUS. Well, I think that goes to the heart of what I have said previously before this body and the House, Senator. And that is, that one of the crucial questions it seems to me is the pace at which damage is occurring. Should we assume that what we are looking at is an emergency as opposed to a problem that is taking much longer in terms of its effects. We have evidence cutting both ways. Some of the more recent evidence indicates that we have a longer range problem on our hands.

In fact, a report is coming out from the National Academy in the next few days that, I think, sharpens this debate over the pace at which lake acidification is occurring rather well.

If we have a longer term problem, then obviously we can do this more cheaply, because we can have the benefits of additional research on technology that might be able to reduce SO2 more cheaply. We can have more time to phase out older powerplants that would have to be retrofitted with the scrubber under Senator Mitchell's approach, which is a very expensive way of reducing sulfur oxide.

So if we have more time, if the problem we faced is longer in time, then obviously we can do this with less social disruption in terms of the effect on coal miners and other affected jobs, and less expensively, because we can take advantage of new technology which we may well be able to develop.

Senator JOHNSTON. Mr. Ruckelshaus, you have a very good reputation as being fair-minded and committed to the environment. I wish you would help those of us who are confused about what the extent of this damage is. Can you give me your best judgment as to who is right? Senator Mitchell says—and I have great respect for him—that the damage resulting from acid deposition has not diminished, and that it is, in fact, it is continuing at an unremitting pace. I look at Secretary Hodel's charts here, and they show since about 1970, a sharp reduction in SO_2 emissions. I know there are a lot of different theories on this matter.

What is your best judgment? Is the problem worsening or is it getting better?

Mr. RUCKELSHAUS. Senator, you're asking one lawyer to mediate a dispute between two other lawyers, and none of us are scientists. [Laughter.]

Senator FORD. Well, when you're appointed judge——

[Laughter.]

Mr. RUCKELSHAUS. I don't think what they're saying is necessarily inconsistent.

What Secretary Hodel's charts show is what has happened to sulfur oxide emission over the last decade and a half. Those charts are correct, I mean up to the point at which they stop. SO_2 emissions have been coming down in this country since the early- to mid-seventies as a result of the passage of the Clean Air Act.

And his projections, and ours, show that between now and the year 2000 will roughly remain flat in SO_2 emissions. I don't think Senator Mitchell disagreed with that.

The question that Senator Mitchell raises is whether the effect of sulfur oxide emissions turning into sulfates which come down in the form of acid deposition is a cumulative effect, or whether it's a rapid response effect.

In other words, if we left emission levels as they are now, is the damage that we have now seen already done and not likely to get any worse, or are we likely to see a continued worsening in the impact on the environment?

Now, that is precisely the question that I asked this committee, where I mentioned this report is coming out in the next couple of days from the National Academy—precisely the question I asked them to address, because this was an issue that had arisen over the last several months as a result of the research that is currently going on.

Senator JOHNSTON. Do you know what they'll say?

Mr. RUCKELSHAUS. Yes. They'll say they're divided on the question.

[Laughter.]

Mr. RUCKELSHAUS. Therefore, so am I.

[Laughter.]

Mr. RUCKELSHAUS. But they do say, and I think it's significant what they say—that they can research that issue. That issue is a researchable one. And they suggest areas of our research, which we will pursue very vigorously to try to get an answer to that question of whether what we're witnessing here is a cumulative effect or what is called a rapid response effect; in other words, what you see very rapidly is what you're going to get, and then assuming things don't get any worse in the form of deposition, we won't see any worsening of the effect on at least aquatic systems.

Senator JOHNSTON. Thank you.

The CHAIRMAN. Senator Evans.

Senator EVANS. I can't let that one pass without suggesting, if you ask a researcher what is most needed, they'll almost always say more research. That's the nature of their occupation.

Mr. Ruckelshaus, you said that it would be difficult, or impossible at this point to tell when you could get to the point of an answer, but can you enlighten us on what are the measuring points? How are you going to decide when you're there? We may not be able to tell when we get there, but we ought to have a target we're shooting at so that we can say all right, now we can take action, or fail to take action, or make a final decision.

Mr. RUCKELSHAUS. Yes. I think, Senator, that's certainly a relevant question. It also is true that we may discover information that makes it less likely that we're ready to make a recommendation right now as it relates to a control strategy.

On the other hand, if we were to find—I mean, the way I have attempted to pose the question is whether we have an emergency on our hands, or whether we have something that is a much longer-term kind of a phenomenon at which we could pace our response to it consistent with the nature of whatever harm may be occurring.

And if we were to find, for instance, that in a lake survey which we have already started and will be completing through this climatic cycle. We will be doing a very intensive survey this fall of some 3,000 lakes throughout the country.

If we were to find that the problem were much more widespread than we thought, if we were to find as a result of that survey that the deterioration that we could tell by lake coring was occurring much more rapidly than we thought, then we might be willing to make a recommendation for a solution much more quickly.

By the same token, if our monitoring system which we are now putting in place nationwide, the National Trends Network System, were to show that the deterioration in the forests, in the watersheds was occurring more rapidly than we had earlier thought, that might lead us to make a recommendation for a control strategy more quickly.

If the information we were picking up on the forests should show us, through some breakthrough, which we now don't fully understand, that the problem really is sulfur oxide, that seems to be what's causing the problem in the forest, and there were general scientific agreement on that, then that might lead us to suggest a reduction in sulfur oxide or a sulfur oxide control strategy.

What the scientists are now willing to say is we don't know what's the problem, we have seen this phenomenon in the forests, we don't know what's causing it, whether it's a natural cause, an environmental cause, air pollution cause, and if it's air pollution, which of the pollutants is really at fault, or whether it's some combination of all those things. If we should make a scientific breakthrough in that area as a result of our research, we might be willing to make a control strategy recommendation more quickly.

Senator **Evans**. Can you share with us, or do you have set forth in any more specific fashion the sort of track that you would follow: here is research going on, we expect to have some answer by date "X", and you can identify, presumably, several kinds of answers and with each of those kinds of answer, either yes we do something, or no it requires further research or further action? Have you gone down the line enough to share with us sort of what those next stages will be, and what the timeframe with those alternative answers to the initial research might lead to?

Mr. **Ruckelshaus**. It might be more helpful to you, Senator, and to the committee if I were to submit that for the record. However, it is a question that I constantly put to our own scientists, and I get an answer that isn't altogether satisfactory, even a division of answers from the scientists as to exactly when we could expect to get the answers. But I certainly will try to do that for you, as I have asked them to do that for me.

Senator **Evans**. OK. Just add my urgency to yours.

You mention in your testimony that current knowledge did not tell us whether the offending pollutants are sulfate, nitrates, oxidants, heavy metals, or some combination. And, of course, here we're dealing with primarily one pollutant, but isn't it likely that we will attempt to reduce pollutants in parallel and not sequentially?

Mr. **Ruckelshaus**. Yes, it may be likely if that is shown to be necessary. On the other hand, it is certainly more expensive. If we were to try to control sulfur oxides, nitro oxides, and even hydrocarbons in a more general sense in combination, that is a more expensive thing to do. It is even more expensive yet if we were to do it in sequence. If we were to say, these are the pollutants we need to control, and if you throw heavy metals in in addition as a result of the combustion of coal, if we were to try to reduce all of those, if that were the conclusion that our research information led us to, then it certainly is easier to do it all at once than to decide to do it in sequence.

And, as all of the bills pending before the Congress that try to recommend control strategy suggest, we at this point control only sulfur oxides.

In the case of the forest, we may discover, after having spent literally billions of dollars, we're controlling the wrong pollutant, which would mean we would have to go back and craft technology or other kinds of controls on the other pollutants that would be put on in addition to those that control sulfur oxide.

Senator **Evans**. Let me turn briefly, Mr. Chairman, to Secretary Hodel.

The chart at the end of your testimony indicates, or seems to indicate, that sulfur dioxide emissions have decreased, or at least leveled off during the course of the last few years. That, presumably, is on a nationwide basis. Do you have any breakdown geographically as to where that's occurring, or is it differential in different parts of the country, or could you submit for us some breakdown?

Mr. **Hodel**. Yes, we do have such material. I'm advised both EPA and DOE have it, which I will be happy to supply for the record.

[The information follows:]

Geographical Breakdown of Historical Emissions Estimates

The national historical SO_2 emissions estimates are taken from EPA document 450/4-83-024, February 1984. That document does not breakdown emissions by state or region.

A contractor, Pacific Environmental Services (PES), is currently estimating historic emissions of SO_2 and NO_x from 1900 to 1980, with breakdowns by Federal Region and State. The project is being conducted for Task Group B - Manmade Sources - of the National Acidic Precipitation Assessment Program. The project has not been completed. However, a preliminary draft report was prepared on October 5, 1983. That draft contains estimates of emission trends by Federal Region (Figure 2 Pages 1-8&9) and by state and sector (Tables 1-6, Pages 3-689 to 3-697).

The estimated trend breakdowns are preliminary and may change before final publication. Therefore, they should not be used for precise, quantitative assessments. The qualitative trend directions are not likely to change dramatically, so the preliminary report may be useful for general discussions of relative trends.

One final caveat is necessary. The national emission trend estimates in two documents do not match perfectly. They track quite well for utilities, fairly well for total SO_2 emissions, and not very well for industrial emissions (see attached figure). Furthermore, the February EPA publication extends to 1982 while the draft PES report stops in 1980. The final PES report will attempt to reconcile these differences. This further underlines the preliminary nature of the PES draft and the admonition to use its results qualitatively and with caution.

The historical emissions of sulfur dioxide for each region of the U.S.A., as shown in Figure 2 of the draft PES report, can be characterized as follows, subject to the proceeding caveats:

Regions 1 and 2 (New England, New York, New Jersey)

Emissions of SO_2 remained fairly constant at moderate levels from 1900 to 1970, with fluctuations following economic conditions. Emissions dropped sharply (~ 30%) between 1970 and 1975, and remained steady through 1980.

Region 3 (Pennsylvania, Virginia, West Virginia, Maryland)

Emissions of SO_2 increased dramatically (tripled) from a moderate base between 1950 and 1970. The rapid increase was halted in 1970 but emissions have declined only slightly since then.

Region 4 (Southeast)

Emissions of SO_2 were similar to Regions 1 and 2 through 1955. Emissions increased rapidly (~ 80%) between 1955 and 1965. Emissions have declined slowly but steadily since 1965 (~15%).

Region 5 (Midwest)

This region has been the largest emitter of SO_2 since 1900, with emissions roughly 3 times those from Regions 1 and 2 or 4, and fluctuating with economic conditions similar to those regions. SO_2 emissions peaked in the 1965-70 period and then dropped rapidly (~25%) through 1980.

Region 6 (Texas, New Mexico, Oklahoma, Arkansas, Louisiana)

Low and fairly constant SO_2 emissions from 1900-1970, with a minimum in the 1950-1970 period. Emissions have increased sharply (~ 30%), from a low base, since 1970.

Region 7 (Kansas, Nebraska, Iowa, Missouri)

Moderate SO_2 emissions in the early part of the century (similar to Regions 1 and 2, and 4) declining to a minimum in the 1950-1970 period. Emissions rose slightly between 1970 and 1975 and remained constant through 1980.

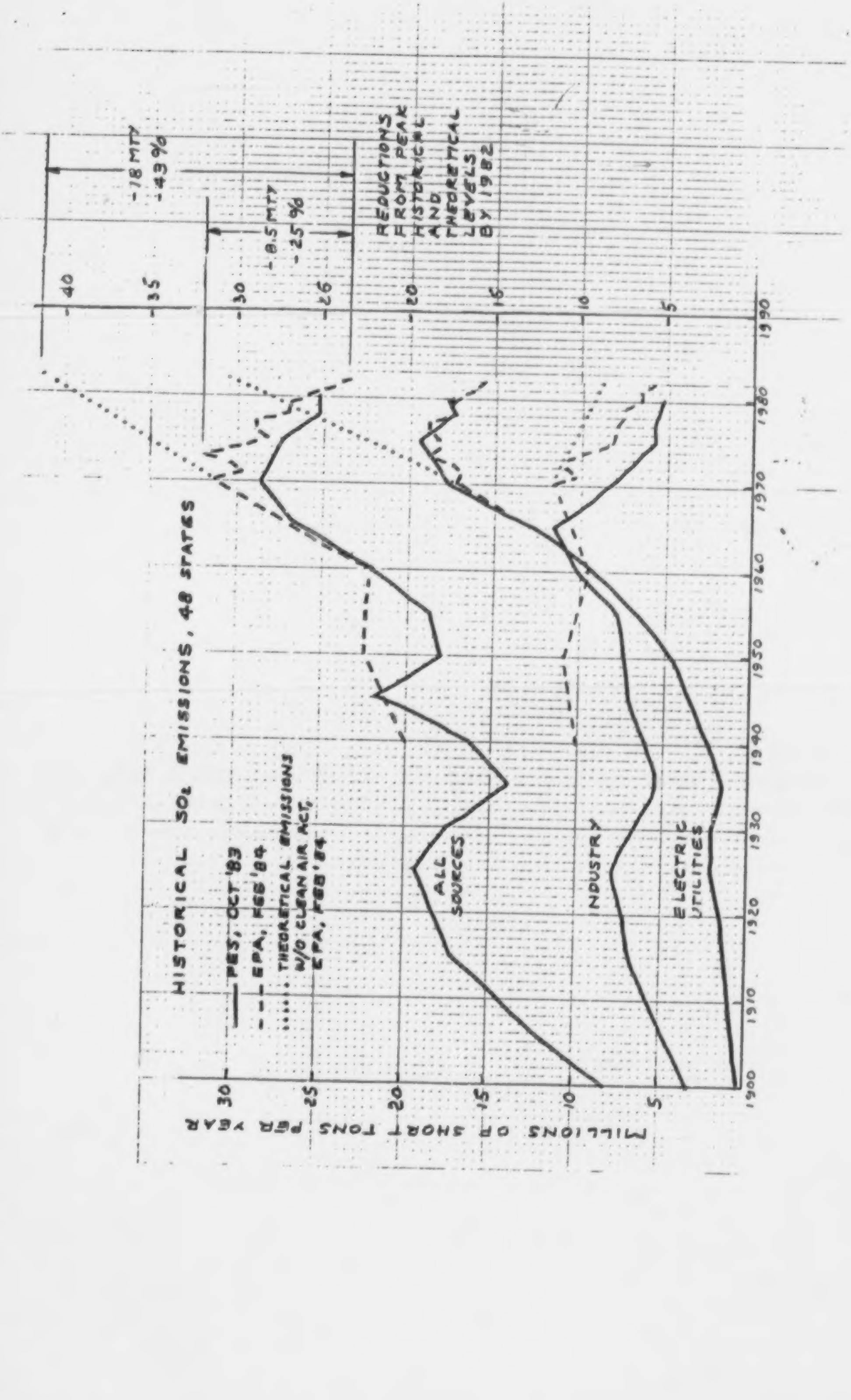
Regions 8, 9 and 10 (West Coast and Rocky Mountain)

Emissions of SO_2 were low until WW II, then tripled to moderate levels between 1940 and 1950. Another rise between 1960 and 1970 peaked in 1970 and then declined rapidly (~ 40%) through 1980.

Copies of both the EPA report and PES draft are provided.

(1. Extract from, "National Air Pollutant Emission Estimates, 1940-1982", by the Environmental Protection Agency. (EPA document number 450/4-83-024). February 1984. The full document is retained in the full Committee files.

2. "Historic Emissions of Sulfur and Nitrogen Oxides in the United States from 1900 to 1980", by Gerhard Gschwandtner, Karin C. Gschwandtner, and Kevin Eldridge, Pacific Environmental Services, Inc., Durham, North Carolina. (EPA Contract No. 68-02-3511, Assignment No. 31. Project Officer, J. David Mobley, Industrial Environmental Research Laboratory). October 5, 1983.)



HISTORICAL SO_2 EMISSIONS, 48 STATES

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

[illegible]

Air

EPA

National Air Pollutant Emission Estimates, 1940-1982

EPA-450/4-83-024

National Air Pollutant Emission Estimates, 1940-1982

Monitoring and Data Analysis Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

February 1984

This report is published by the U.S. Environmental Protection Agency to report information of general interest in the field of air pollution. Copies are available free of charge to Federal employees, current contractors and grantees, and nonprofit organizations - as supplies permit - from the Library Services Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711; or, for a fee, from the National Technical Information Services, 5285 Port Royal Road, Springfield, Virginia 22161.

Publication No. EPA-450/4-83-024

ABSTRACT

This report presents estimates of trends in nationwide air pollutant emissions for the five major pollutants: particulates, sulfur oxides, nitrogen oxides, volatile organic compounds, and carbon monoxide. Estimates are presented for each year from 1940 through 1982. Emission estimates are broken down according to major classifications of air pollution sources. A short analysis of trends is given, along with a discussion of methods used to develop the data.

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NATIONAL AIR POLLUTANT EMISION ESTIMATES

1940-1982

1. SUMMARY

The primary objectives of this publication are to provide current estimates of nationwide emissions for five major pollutants: particulate matter (PM), sulfur oxides (SO_2), nitrogen oxides (NO_x), volatile organic compounds (VOC), and carbon monoxide (CO). Estimates are presented for 1940, 1950, and 1960 to give a historical perspective of national air pollutant emissions, and for 1970 through 1982 as an indication of recent trends. These data entirely replace those published earlier for 1940-1980 in EPA report National Air Pollutant Emission Estimates, 1940-1980 (EPA-450/4-82-001) and for 1970-1981 in National Air Pollutant Emission Estimates, 1970-1981 (EPA-450/4-82-012). Because of modifications in methodology and use of more refined emission factors, data from this report should not be compared with data in these earlier reports.

Reporting of emissions on a nationwide basis, while useful as a general indicator of pollutant levels, has definite limitations. National totals or averages are not the best guide for estimating trends for particular localities. Yet, it is important that some criteria be established for measurement of national progress in the control of air pollutant emissions. The emission estimates presented herein represent calculated estimates based on standard emission inventory procedures. Since these data are estimates only and do not represent the results of any program for the measurement of actual emissions, their accuracy is somewhat limited. Similarly, it would not necessarily be expected that these emission estimates would be in agreement with emission estimates derived through a different emission inventory procedure. The principal objective of compiling these data is to identify probable overall changes in emissions on a national scale. It should be recognized that these estimated national trends in emissions may not be representative of local trends in emissions or air quality.

TABLE 1

SUMMARY OF NATIONAL EMISSION ESTIMATES

Units of Measurement	Year	Particulates	Sulfur Oxides	Nitrogen Oxides	Volatile Organics	Carbon Monoxide
Teragrams/Year (10^6 metric tons/year)	1940	22.4	18.1	6.7	17.1	79.8
	1950	24.2	20.4	9.2	19.3	85.3
	1960	20.9	20.1	12.7	21.9	87.9
	1970	18.0	28.4	18.1	25.3	100.2
	1971	16.8	26.9	18.5	24.5	98.6
	1972	15.0	27.6	19.7	24.5	95.7
	1973	13.9	28.9	20.2	24.0	91.6
	1974	12.3	27.0	19.7	22.5	86.5
	1975	10.3	25.7	19.2	21.0	82.4
	1976	9.6	26.3	20.4	22.1	87.2
	1977	9.0	26.3	21.0	21.9	83.0
	1978	8.9	24.6	21.2	22.4	82.3
	1979	9.0	24.6	21.3	21.9	79.5
	1980	8.6	23.3	20.7	20.8	77.6
	1981	8.1	22.5	20.9	19.4	75.3
	1982	7.5	21.4	20.2	18.2	73.6
(10^6 short tons/year)	1940	24.7	20.0	7.4	18.8	88.0
	1950	26.7	22.5	10.1	21.3	94.0
	1960	23.0	22.2	14.0	24.1	96.9
	1970	19.8	31.3	20.0	27.9	110.4
	1971	18.5	29.7	20.4	27.0	108.7
	1972	16.5	30.4	21.7	27.0	105.5
	1973	15.3	31.9	22.3	26.5	101.0
	1974	13.6	29.8	21.7	24.8	95.3
	1975	11.4	28.3	21.2	23.1	90.8
	1976	10.6	29.0	22.5	24.4	96.1
	1977	9.9	29.0	23.1	24.1	91.5
	1978	9.8	27.1	23.4	24.7	90.7
	1979	9.9	27.1	23.5	24.1	87.6
	1980	9.5	25.7	22.8	22.9	85.5
	1981	8.9	24.8	23.0	21.4	83.0
	1982	8.3	23.6	22.3	20.1	81.1
Change 1940-1982		-67%	+18%	+201%	+6%	-8%
Change 1970-1982		-58%	-25%	+12%	-28%	-27%

2. NATIONWIDE EMISSION TRENDS, 1940-1982

Table 1 gives a summary of total national emission estimates for 1940-1982. Tables 2 through 11 present summaries for each year according to the five major categories of sources: transportation, stationary source fuel combustion, industrial processes, solid waste disposal, and miscellaneous sources. More detailed breakdowns of emissions for 1970 through 1982 are given in Tables 12 through 16 for transportation, Tables 17 through 21 for stationary source fuel combustion, and in Tables 22 through 26 for industrial processes.

In the industrial process tables the Standard Industrial Classification (SIC) which the process is included is shown. These designations are not intended to represent the complete emissions for all SIC categories and serve only to identify and classify the industrial process shown.

In all tables data are reported in metric units, either as teragrams (10^{12} grams) or gigagrams (10^9 grams) per year. One teragram equals approximately 1.1×10^6 short tons and one gigagram equals approximately 1.1×10^3 short tons.

2.1 Particulates

Particulate emissions result primarily from industrial processes and from fuel combustion in stationary sources. For 1940 and 1950, emissions from transportation (coal combustion by railroads) and miscellaneous sources (forest fires) were also significant. Emissions from fuel combustion and industrial processes did not change substantially from 1940 to 1970. Since 1970, emissions from these categories have been substantially reduced as the result of installation of air pollution control equipment. Particulate emissions from transporation decreased substantially from 1940 to 1960 as the result of the obsolescence of coal-burning railroad locomotives. From 1960 to 1982, particulates from transportation increased due to increased travel by highway motor vehicles. Miscellaneous source emissions decreased substantially from 1940 to 1970, primarily due to a major reduction in the acreage burned by forest wildfires. Solid waste emissions increased from 1940 to 1970, but declined substantially to 1982 as the result of air pollution regulations prohibiting or limiting the burning of solid waste.

2.2 Sulfur Oxides

Sulfur oxide emissions occur mostly from stationary source fuel combustion and to some extent, from industrial processes. Sulfur oxide emissions from combustion of coal by railroad locomotives were also significant in 1940 and 1950. Emissions from solid waste disposal and miscellaneous sources have always been minor. Emissions from stationary source fuel combustion increased greatly from 1940 to 1970, primarily from increased coal combustion by electric utilities.

From 1970 to 1982, emissions from fuel combustion have decreased slightly. During this time period, fuel combustion, particularly of sulfur-bearing coal and oil, continued to increase, but the average sulfur contents of fuels decreased and a limited number of pollution control systems (flue gas desulfurization) were installed. Emissions from industrial processes increased from 1940 to 1970 reflecting increased industrial production. From 1970 to 1982, industrial process emissions decreased primarily due to control measures by primary nonferrous smelters and sulfuric acid plants.

2.3 Nitrogen Oxides

Nitrogen oxide emissions are produced largely by stationary source fuel combustion and transportation sources. Emissions have steadily increased over the period from 1940 to 1970 as the result of increased fuel combustion. From 1970 to 1982, the size of the increase was reduced somewhat by controls installed on highway motor vehicles and to a lesser extent by controls on coal-fired electric utility boilers. Nitrogen oxide emissions by industrial processes increased from 1940 to 1970, but have remained about constant since then.

2.4 Volatile Organic Compounds (VOC)

The largest sources of VOC emissions are transportation sources and industrial processes. Miscellaneous sources, primarily forest wildfires and non-industrial consumption of organic solvents, also contribute significantly to total VOC emissions. Emissions from stationary source fuel combustion and solid waste disposal are relatively small. Transportation source emissions increased greatly from 1940 to 1970, primarily as the result of increased travel by highway motor vehicles. Since 1970 air pollution controls installed on motor vehicles have been effective in reducing VOC emissions. Industrial process emissions have increased, generally reflecting increased levels of industrial production. Controls installed on industrial processes since 1970 have had a modest effect in preventing additional increases in VOC emissions. Emissions from stationary source combustion declined from 1940 through the mid-1970's and then increased to 1982, reflecting primarily the trend in residential wood combustion.

2.5 Carbon Monoxide

Transportation sources are the largest emitters of carbon monoxide. Major increases in emissions occurred from 1940 to 1970 as the result of increased motor vehicle travel. From 1970 to 1982, transportation emissions decreased as the result of highway vehicle emission controls, despite continued increases in highway vehicle travel. Emissions from stationary source fuel combustion have declined from 1940 through the mid-1970's and then increased slightly to 1982.

Prior to 1970, residential coal and wood combustion contributed significantly to CO emissions. However, as residential use of coal has been replaced by other fuels, residential emissions have declined. Beginning in the late 1970's residential combustion of wood has increased, however, and as a result CO emissions from residential fuel combustion increased. Carbon monoxide emissions from industrial processes increased from 1940 to 1950 but have declined somewhat since then. The decline is due largely to the obsolesence of a few high-polluting industrial processes such as carbon black manufacture by the channel process and limited installation of control equipment on other processes. These factors have been significant enough to offset growth in industrial production which would otherwise have caused a net increase in emissions. Carbon monoxide emissions from solid waste disposal increased from 1940 to 1970, but have subsequently declined as the result of air pollution control efforts. Substantial emissions of carbon monoxide from forest fires occurred in 1940. In later years, these emissions have been much smaller due to improved fire prevention efforts and more effective suppression of wildfires.

TABLE 2

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF PARTICULATES (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	0.2	0.3	0.6	0.9
Aircraft	0.0	0.0	0.0	0.1
Railroads	2.4	1.7	0.1	0.1
Vessels	0.1	0.1	0.0	0.0
Other Off-Highway	0.0	0.0	0.0	0.1
Transportation Total	2.7	2.1	0.7	1.2
Stationary Source Fuel Combustion				
Electric Utilities	1.3	2.0	2.8	2.3
Industrial	3.3	2.7	1.7	1.6
Commercial Institutional	0.4	0.5	0.1	0.1
Residential	2.1	1.5	0.9	0.5
Fuel Combustion Total	7.1	6.7	5.5	4.5
Industrial Processes				
Iron and Steel Mills	3.0	3.5	1.7	1.2
Primary Metal Smelting	0.6	0.6	0.5	0.5
Secondary metals	0.3	0.3	0.2	0.2
Mineral Products	1.7	2.6	3.4	2.6
Chemicals	0.3	0.4	0.3	0.2
Petroleum Refining	0.0	0.0	0.1	0.1
Wood Products	0.4	0.7	0.8	0.6
Food and Agriculture	0.8	0.8	0.9	0.8
Mining Operations	1.3	3.4	4.1	3.9
Industrial Processes Total	8.4	12.3	12.0	10.1
Solid Waste Disposal				
Incineration	0.3	0.3	0.4	0.4
Open Burning	0.2	0.3	0.5	0.7
Solid Waste Total	0.5	0.6	0.9	1.1
Miscellaneous				
Forest Fires	2.9	1.7	1.0	0.7
Other Burning	0.8	0.8	0.8	0.4
Misc. Total	3.7	2.5	1.8	1.1
Total of All Sources	22.4	24.2	20.9	18.0

NOTE: One teragram equals 10^{12} grams (10^6 metric tons) or approximately 1.1 x 10^6 short tons. A value of zero indicates emissions of less than 50,000 metric tons.

TABLE 3

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF SULFUR OXIDES (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	0.0	0.1	0.1	0.3
Aircraft	0.0	0.0	0.0	0.0
Railroads	2.7	2.0	0.2	0.1
Vessels	0.2	0.2	0.1	0.1
Other Off-Highway	0.0	0.0	0.0	0.1
Transportation Total	2.9	2.3	0.4	0.6
Stationary Source Fuel Combustion				
Electric Utilities	2.2	4.1	8.4	15.8
Industrial	5.5	5.2	3.5	4.1
Commercial Institutional	1.0	1.7	1.0	0.9
Residential	2.3	1.9	1.1	0.5
Fuel Combustion Total	11.0	12.9	14.0	21.3
Industrial Processes				
Iron and Steel Mills	2.6	2.9	3.1	3.8
Primary Metal Smelting	0.1	0.1	0.1	0.1
Secondary metals	0.2	0.4	0.4	0.6
Mineral Products	0.2	0.3	0.6	0.7
Chemicals	0.3	0.5	0.4	0.5
Petroleum Refining	0.0	0.0	0.0	0.0
Wood Products	0.3	0.5	0.5	0.6
Food and Agriculture	0.0	0.0	0.1	0.1
Industrial Processes Total	3.7	4.7	5.2	6.4
Solid Waste Disposal				
Incineration	0.0	0.0	0.0	0.0
Open Burning	0.0	0.0	0.0	0.0
Solid Waste Total	0.0	0.0	0.0	0.0
Miscellaneous				
Forest Fires	0.0	0.0	0.0	0.0
Other Burning	0.5	0.5	0.5	0.1
Misc. Total	0.5	0.5	0.5	0.1
Total of All Sources	18.1	20.4	20.1	28.4

NOTE: One teragram equals 10^{12} grams (10^6 metric tons) or approximately 1.1×10^6 short tons. A value of zero indicates emissions of less than 50,000 metric tons.

TABLE 4

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF NITROGEN OXIDES (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	1.3	2.0	3.5	6.0
Aircraft	0.0	0.0	0.0	0.1
Railroads	0.6	0.9	0.7	0.6
Vessels	0.1	0.1	0.1	0.1
Other Off-Highway	0.2	0.4	0.5	0.8
Transportation Total	2.2	3.4	4.8	7.6
Stationary Source Fuel Combustion				
Electric Utilities	0.6	1.2	2.3	4.5
Industrial	2.2	2.9	3.7	3.9
Commercial Institutional	0.2	0.3	0.3	0.3
Residential	0.3	0.3	0.4	0.4
Fuel Combustion Total	3.3	4.7	6.7	9.1
Industrial Processes				
Petroleum Refining	0.1	0.1	0.2	0.2
Chemicals	0.0	0.0	0.1	0.2
Iron and Steel Mills	0.0	0.1	0.1	0.1
Pulp Mills	0.0	0.0	0.0	0.0
Mineral Products	0.1	0.1	0.1	0.2
Industrial Processes Total	0.2	0.3	0.5	0.7
Solid Waste Disposal				
Incineration	0.0	0.1	0.1	0.1
Open Burning	0.1	0.1	0.2	0.3
Solid Waste Total	0.1	0.2	0.3	0.4
Miscellaneous				
Forest Fires	0.7	0.4	0.2	0.2
Other Burning	0.2	0.2	0.2	0.1
Misc. Total	0.9	0.6	0.4	0.3
Total of All Sources	6.7	9.2	12.7	18.1

NOTE: One teragram equals 10^{12} grams (10^6 metric tons) or approximately 1.1 x 10^6 short tons. A value of zero indicates emissions of less than 50,000 metric tons.

TABLE 5

1940-1970 SUMMARY OF ESTIMATED EMISSIONS OF VOLATILE ORGANIC COMPOUNDS (TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	3.9	5.8	8.6	9.4
Aircraft	0.0	0.1	0.2	0.2
Railroads	0.5	0.5	0.2	0.2
Vessels	0.0	0.1	0.2	0.3
Other Off-Highway	0.2	0.4	0.5	0.5
Transportation Total	4.6	6.9	9.7	10.6
Stationary Source Fuel Combustion				
Electric Utilities	0.0	0.0	0.0	0.0
Industrial	0.1	0.1	0.1	0.1
Commercial Institutional	0.0	0.0	0.0	0.0
Residential	3.8	2.5	1.5	0.8
Fuel Combustion Total	3.9	2.6	1.6	0.9
Industrial Processes				
Chemicals	0.8	1.2	1.1	1.6
Petroleum Refining	0.4	0.5	0.7	0.7
Iron and Steel Mills	0.1	0.1	0.1	0.1
Mineral Products	0.0	0.0	0.0	0.0
Food and Agriculture	0.1	0.1	0.2	0.2
Industrial Organic Solvent Use	1.0	2.1	2.4	4.0
Petroleum Product Production and Marketing	0.8	1.2	1.6	2.1
Industrial Processes Total	3.2	5.2	6.1	8.7
Solid Waste Disposal				
Incineration	0.4	0.4	0.5	0.5
Open Burning	0.5	0.6	0.9	1.3
Solid Waste Total	0.9	1.0	1.4	1.8
Miscellaneous				
Forest Fires	3.1	1.7	0.9	0.7
Other Burning	0.6	0.6	0.5	0.3
Misc. Organic Solvent Use	0.8	1.3	1.7	2.3
Misc. Total	4.5	3.6	3.1	3.3
Total of All Sources	17.1	19.3	21.9	25.3

NOTE: One teragram equals 10^{12} grams (10^6 metric tons) or approximately 1.1×10^6 short tons. A value of zero indicates emissions of less than 50,000 metric tons.

TABLE 6

1940-1970 SUMMARY OF ESTIMATED
EMISSIONS OF CARBON MONOXIDE
(TERAGRAMS/YEAR)

Source Category	1940	1950	1960	1970
Transportation				
Highway Vehicles	22.4	33.6	46.9	64.6
Aircraft	0.0	0.8	1.6	0.9
Railroads	3.7	2.8	0.3	0.3
Vessels	0.2	0.2	0.6	1.1
Other Off-Highway	3.4	6.7	8.0	6.8
Transportation Total	29.7	44.1	57.4	73.7
Stationary Source Fuel Combustion				
Electric Utilities	0.0	0.1	0.1	0.2
Industrial	0.4	0.5	0.6	0.7
Commercial Institutional	0.1	0.1	0.0	0.1
Residential	13.2	9.2	5.4	2.9
Fuel Combustion Total	13.7	9.9	6.1	3.9
Industrial Processes				
Chemicals	3.8	5.3	3.6	3.1
Petroleum Refining	0.2	2.4	2.8	2.0
Iron and Steel Mills	1.5	1.1	1.3	1.6
Primary Metal Smelting	0.0	0.1	0.3	0.6
Secondary Metals	1.0	1.4	1.0	1.1
Pulp Mills	0.1	0.2	0.3	0.6
Industrial Processes Total	6.6	10.5	9.3	9.0
Solid Waste Disposal				
Incineration	2.0	2.5	2.5	2.7
Open Burning	1.3	1.8	2.6	3.7
Solid Waste Total	3.3	4.3	5.1	6.4
Miscellaneous				
Forest Fires	22.8	12.8	6.7	5.1
Other Burning	3.7	3.7	3.3	2.1
Misc. Total	26.5	16.5	10.0	7.2
Total of All Sources	79.8	85.3	87.9	100.2

NOTE: One teragram equals 10^{12} grams (10^6 metric tons) or approximately 1.1×10^6 short tons. A value of zero indicates emissions of less than 50,000 metric tons.

October 5, 1983

HISTORIC EMISSIONS OF SULFUR AND NITROGEN OXIDES IN THE UNITED STATES FROM 1900 TO 1980

by

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EPA Contract No. 68-02-3511
Assignment No. 31

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FOREWORD

This report summarizes work which began in November, 1982 and was completed in September, 1983. The work was conducted under a contract with the U.S. Environmental Protection Agency. The report presents estimates of the historic emissions of sulfur dioxide and nitrogen oxides on the state level. Emission estimates can always be improved upon. For this reason, a computer program was developed in order to facilitate changing input data if and when better data becomes available. Since the methodology for calculating the historic emission estimates is consistent from year to year and from state to state, the results can serve as a basis for studying the spatial and temporal changes in emissions and their relationship to the acid precipitation phenomena.

ABSTRACT

This report was prepared for Task Group B, Manmade Sources, of the National Acidic Precipitation Assessment Program. The objective of this work was to provide estimates of historic emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) from 1900 to 1980 on a state by state basis. Emissions were calculated using historic fuel consumption data, information on the sulfur content of fuel and emission factors for manmade pollution sources. The quantity of annual emissions was calculated individually for power plants, industrial boilers and certain industrial processes, commercial and residential furnaces, natural gas pipeline pumping stations, vehicles and other major sources in each state. This report describes the methodology and presents the results in five year increments for each state of the continguous United States. The historic trend in emissions are shown graphically for each consumer category on a state and regional level. The data contained in the report provides a basis for studying terrestial effects and material damage associated with sulfur dioxide and nitrogen oxide over the past eighty years and as a basis for developing national emission control strategies.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

lb -- pound (0.45359 kg)
ton -- short ton (907.1847 kg)
gal -- U.S. gallon (3.7853 liters)
bbl -- barrel (42 U.S. gallons)
cu. ft. -- cubic feet (0.028317 cubic meters)
mi -- mile (1.6093 km)
VMT -- vehicle miles traveled
NA -- not available
NEDS -- National Emissions Data System

SECTION 1

EXECUTIVE SUMMARY

INTRODUCTION

The purpose of this report is to provide information on atmospheric emissions of sulfur dioxide and nitrogen oxides from manmade sources on a state by state basis since 1900. To provide the needed information, data bases of annual fuel consumption by each major source category and the sulfur content of the fuels used, were developed for each state. These data were collected from many publications and were tabulated. Sulfur dioxide and nitrogen oxide emission factors were applied to the data to yield estimates of statewide emissions for major point and area sources. For each state, the emission estimates were tabulated by year and by source category. The emissions were plotted as a function of time to show the temporal trends and also were plotted on a map to show the spatial trends. The project report presents the methodology and the estimated historic emissions both by source category and by fuel type for each state for every fifth year up to 1980.

BACKGROUND

Sulfur dioxide (SO_2) and nitrogen oxide (NO_x) are known precursors of acidic precipitation and deposition. The reduction of emissions of these pollutants is regarded as an essential solution to the problem of increased acidity in the ecosystem. It is unclear how atmospheric emissions have been related to the changes observed in recent years in water chemistry, materials erosion and plant growth observed in the northeast United States and eastern Canada and how to most effectively prevent further environmental damage. The problem is complex. Thus, the primary objective of this project was to provide a reliable historic emission inventory usable in many different research efforts. The inventory must be developed in a manner which is consistent from year to year to study the trend and from state to state to compare the quantities of emissions from various sources.

TABLE 1. FUELS AND SOURCE CATEGORIES

- Bituminous Coal and Lignite
  - Electric Utilities
  - Industrial Boilers and Heating
  - Commercial - Residential Uses
  - Railroads
  - Coke Plants

- Anthracite Coal
  - All Uses

- Residual Oil
  - Electric Utilities
  - Industrial Boilers and Heating
  - Commercial Uses
  - Vessels

- Distillate Oil
  - Electric Utilities
  - Industrial Boilers and Heating
  - Commercial - Residential Uses
  - Railroads
  - Vessels

- Natural Gas
  - Electric Utilities
  - Industrial Boilers and Heating
  - Pipelines
  - Commercial - Residential Uses

- Wood
  - Electric Utilities
  - Industrial Boilers and Heating
  - Commercial Heating
  - Residential Heating

- Gasoline
  - Highway Vehicles
  - Off Highway Vehicles
  - Vessels

- Industrial Processes
  - Copper Smelters
  - Cement Plants

METHODS

The method consisted of three parts. The first part involved collecting and organizing data on the quantity of fuel consumed in each state by specific consumer categories. The fuels and emission sources are presented in Table 1. These include all major point and area sources which collectively account for most of the manmade emissions.

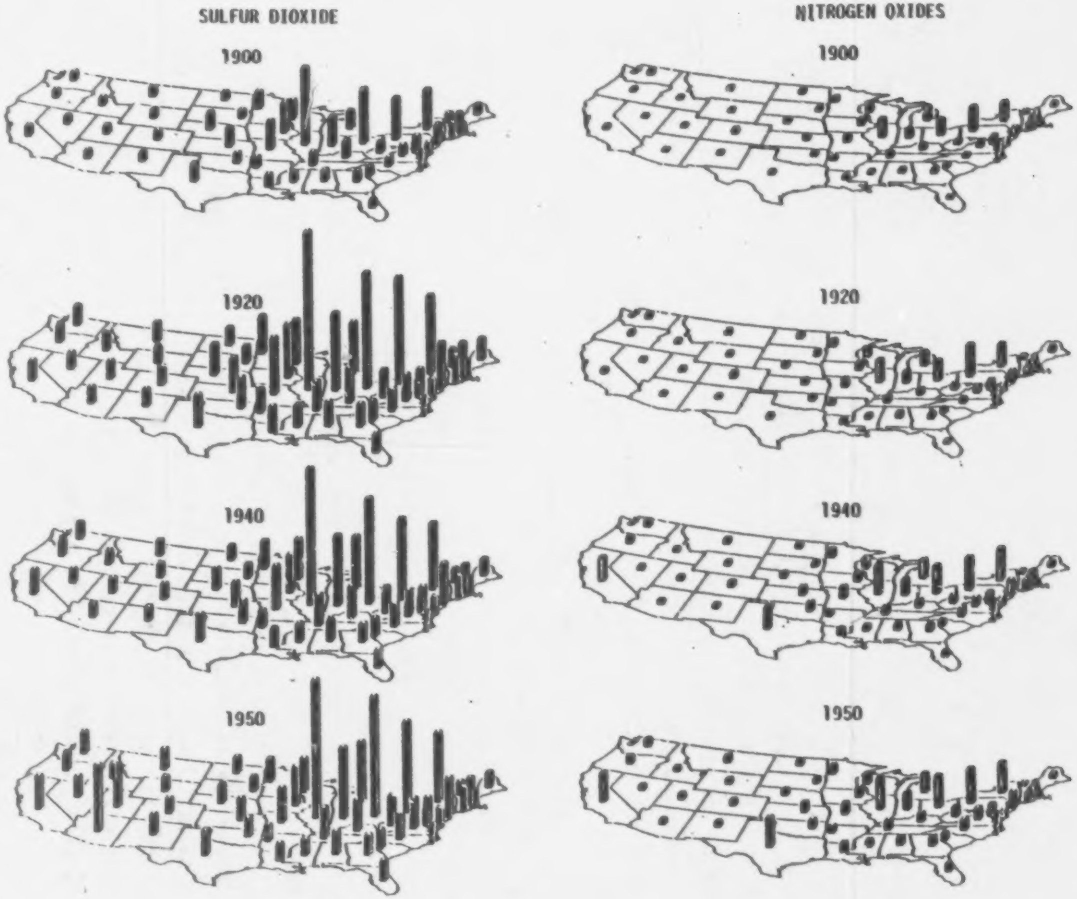
The fuel consumption data for these categories was readily available from Government documents on a state by state basis back to 1950. For earlier years, there are extensive data gaps which had to be filled by making certain assumptions. For example, if state consumption was not reported, the data for the next nearest study year was apportioned according to the national consumption in both years. This assumption introduces some error because state and national fuel consumption may not be directly proportional, but it is reasonable considering a lack of better information.

The second part consisted of collecting data on the sulfur content of the consumed fuels. Average statewide sulfur contents were estimated for each source category by various means described in the report. The earliest year for which average sulfur contents were estimated was 1935 for both coal and fuel oil. These same data were used for all earlier years.

The third part consisted of multiplying the quantity of fuel consumed by an emission factor. A computer program was developed to calculate and display the emission estimates and to facilitate making changes as better input data becomes available. The emission factors for highway vehicles take into account the use of emission controls. All other source categories are mostly uncontrolled with the exception of power plants where the reduction in SO_2 emissions since 1970 was due to flue gas desulfurization systems. This is taken into account in the emission inventory for the electric utilities sector.

RESULTS

The spatial distribution of SO_2 and NO_x emissions across the United States from 1900 to 1980 are shown in Figure 1. Historically, the emissions have been greatest in the heavily industrialized states.



SULFUR DIOXIDE

NITROGEN OXIDES

1900
1920
1940
1950
1900
1920
1940
1950

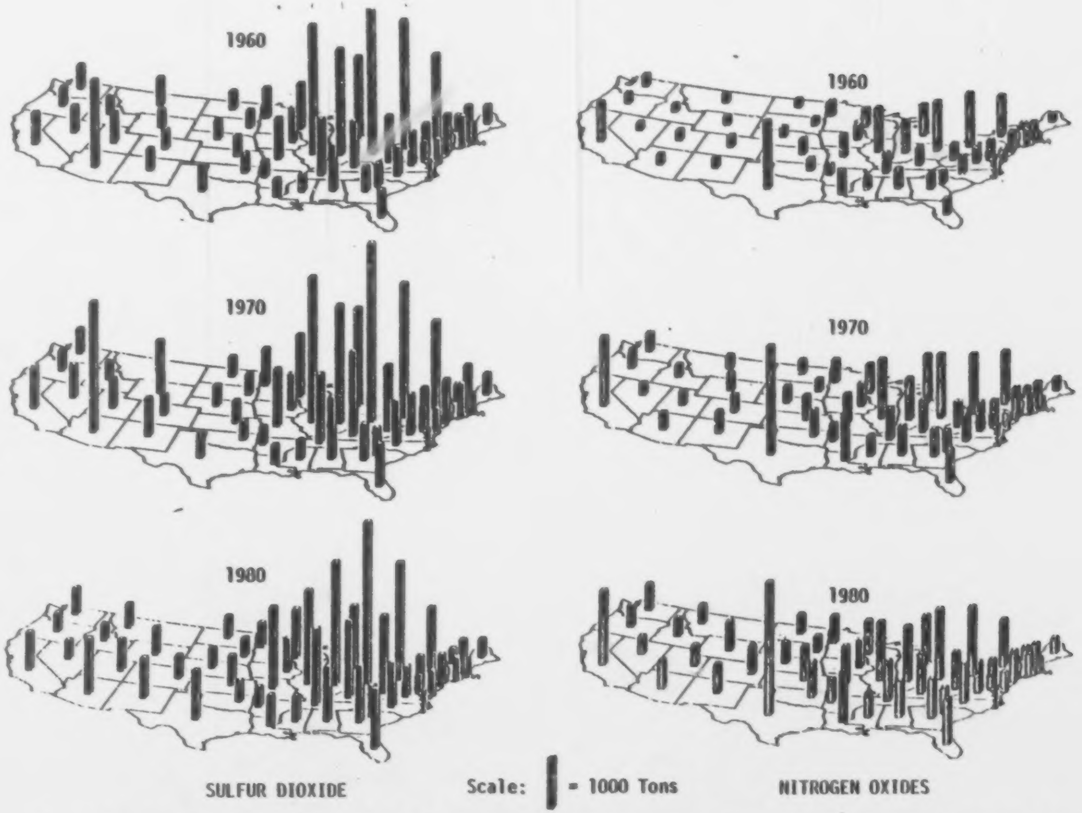

1960
1970
1980
1960
1970
1980
SULFUR DIOXIDE
Scale: ▮ = 1000 Tons
NITROGEN OXIDES

Figure 1. Spatial distribution of total SO_2 and NO_x emissions from 1900 to 1980. (Note that emission estimates for years prior to 1950 may not account for all emissions due to data which were unavailable. For example, copper smelter emissions are not included in totals for Arizona, Utah, Washington, and Tennessee. Other sources are also excluded. Refer to the report for individual state data.)

Significant increases appear to have occurred in the southeastern part of the country in the last 30 years. Even though the SO_2 emissions for years prior to 1950 do not include all sources as explained in the report, the quantities are comparable to the quantities in recent years based on the data that is available. The data indicate that SO_2 emissions in the western United States have not changed very much and that in the New England states, SO_2 emissions have remained about the same for the past sixty years. The spatial distribution of NO_x emissions are also shown on the same scale. NO_x emissions have increased in nearly all parts of the country. The increase is closely related to the recent increase in the use of natural gas and highway vehicles. The most significant increases appear to have occurred in the southeast, midwest and Gulf states, especially in the last twenty years. Changes in emissions can be seen on the state level in the report together with the changes in fuel consumption and sulfur content.

The temporal changes in SO_2 and NO_x emissions by source category are shown in Figure 2 for the different regions of the country. For this display, the states were combined from each of the EPA administrative regions. (Since the emissions in Regions 1 and 2 and in Regions 8, 9 and 10 are small compared to the other regions of the country, these regions are shown as two separate groups.) The data show that electric utilities have contributed significantly to the total SO_2 emissions only in the last thirty years. During the earlier years, industrial boilers, industrial processes, and commercial and residential furnaces contributed the most. The relative contribution of each source category has changed over time with the changes in fuel types used and with the increased use of cleaner fuels especially in the last ten years. NO_x emissions have generally increased from all source categories as a result of industrial growth and urbanization. Highway vehicles are significant sources of NO_x emissions in all regions.

DISCUSSION

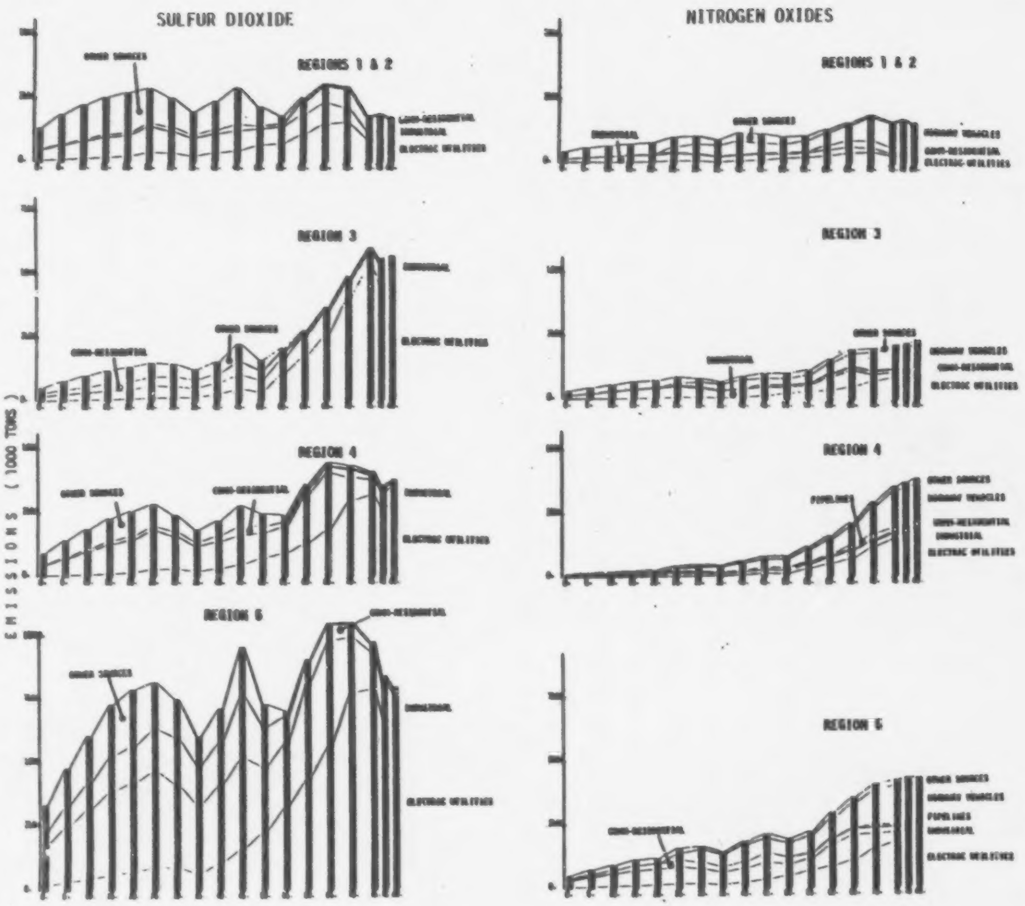
The methodology used to estimate historic emissions is based on historic fuel consumption records. It is consistent from year to year and from state to state. In the case of SO_2, the emissions take into account changes in fuel sulfur content, at least from 1950 to 1980. For the earlier years, considerable data gaps existed which were filled by making assumptions. As a result the emissions are fairly reliable from 1950 to 1980 but the reliability decreases markedly for earlier years.

The results clearly show that not one source category nor region of the country is exclusively responsible for SO_2 and NO_x emissions and therefore, is not the primary cause of acid rain. Many sources contribute to the total emissions and the relative contribution of each source varies from state to state. For example, electric utilities appear to contribute about 85 percent of total SO_2 emissions in Ohio, 51 percent in New York and 55 percent in Virginia in 1980. Thus, a 25 percent reduction in electric utility emissions as has been proposed would result in a much smaller reduction in the total emissions. In 1950 for example, electric utilities contributed even less to the total emissions.

Historically, SO_2 emissions increased up to about 1925, then decreased during the depression, increased during World War II, and subsequently decreased. Since the 1950's, SO_2 emissions have steadily increased up to about 1970 when cleaner coal was used and emission controls were being installed on some power plants. This pattern is most pronounced in the heavily industrialized regions of the country. NO_x emissions appear to have steadily increased especially in the industrialized regions as a result of the increased use of natural gas and gasoline. The most pronounced increase in NO_x emissions appears to have occurred in Texas with the increased use of natural gas.

The estimates do not reflect changes in combustion technology nor burning practices because such information cannot easily be quantified in terms of an emission factor. Rather than assuming emission factors for different time periods for each source category, a constant factor was used. Thus, the resulting emission estimates do not account for changes in technology.

The reliability of the estimates was investigated for 1980. The total state emissions were compared with other emission inventories and an excellent agreement was found. Also, the estimates compare well with the National Emission Trends Report. It is recommended that the project report be consulted for specific data. This summary has only presented an overview of the findings. The data in the report shows the emission trends of both pollutants in greater detail in both time and space.


SULFUR DIOXIDE
NITROGEN OXIDES
REGIONS 1 & 2
REGION 3
REGION 4
REGION 5
REGION 6
OTHER SOURCES
COMM-RESIDENTIAL
INDUSTRIAL
ELECTRIC UTILITIES
HIGHWAY VEHICLES
PIPELINES
EMISSIONS (1000 TONS)

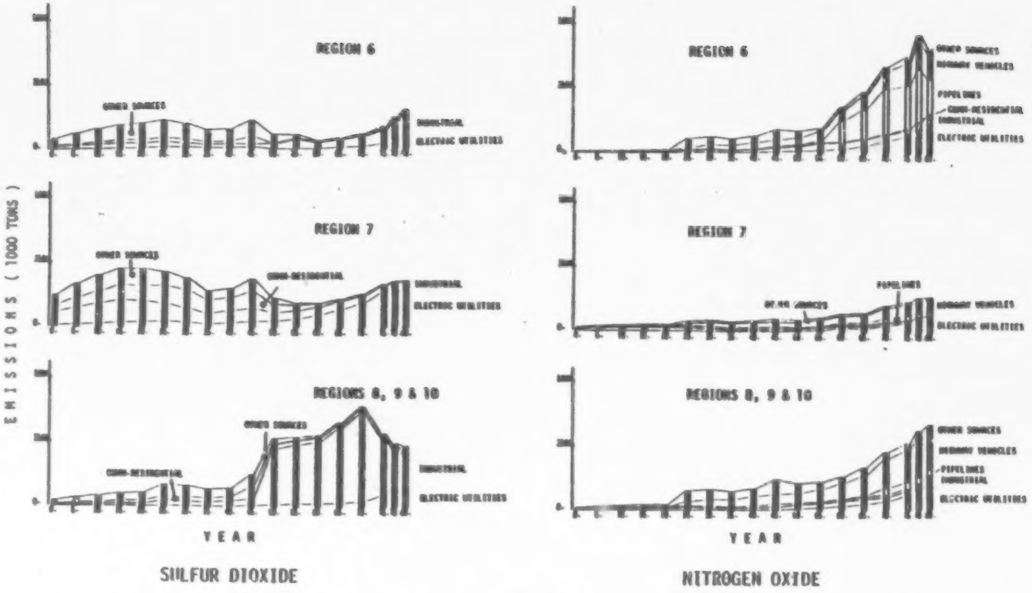


Figure 2. Temporal changes in regional SO_2 and NO_x emissions by source category from 1900 to 1980. (Note that emission estimates for years prior to 1950 may not account for all emissions due to data which is unavailable. The industrial category includes industrial boilers, cement plants, and copper smelters. The emissions from the latter are unaccounted for prior to 1950. Refer to the report for individual state data).

SECTION 2

METHOD

DEFINITION OF TERMS

Annual emissions were estimated for major point and area sources. The individual source categories are defined in Table 2. Exceptions or deviations from these definitions are noted in the data tables. Deviations occur occasionally from year to year depending on the reference used.

FUEL CONSUMPTION DATA

From 1950 to 1980, statewide fuel consumption data were taken from the references identified in Table 3. These references were carefully reviewed to extract only the most useful data. Often it was necessary to use fuel demand, sales or distribution data because consumption data were not available. These cases are footnoted in Table 3. Sometimes fuel consumption was reported for a group of states. As noted in the data table, consumption was then apportioned to the individual state according to the state data available for the nearest later year. Special footnotes to the fuel consumption data for all states year are presented in Table 4 by study year.

The U.S. Department of Energy (DOE) reports fuel use by consumer group from 1960 to 1980. Their data has been adjusted by various means to more closely reflect actual consumption on the state level. For the purposes of this study, it was decided not to use these data because their use might result in a discontinuity in the emissions trend around 1960. Instead, original census data was used for all years. Comparison of the DOE data with the data collected in this study revealed insignificant differences for most categories anyway.

The references for the 1900 to 1945 fuel consumption data are listed in Table 5. The coal consumption data was obtained from Washington University.[37] These are based on state level consumption data for 1889, 1917, 1927, 1957, and 1975 for all categories except railroads. For railroads, the data are based on 1889, 1917, 1937, and 1947. State by state fractions of the total national consumption by each category were calculated for these benchmark years. Then linear interpolations were performed to obtain each state's fraction of the national total for the

TABLE 2. DEFINITION OF SOURCE CATEGORIES

Electric Utilities	Power plants using coal, oil or gas to produce electricity for public consumption.
Industrial Boilers	Manufacturing and mining establishments which use fuel for heat, power and chemical feedstock.
Commercial	Nonmanufacturing organizations such as hotels, restaurants, retail stores, laundries, and other enterprises which use fuel and agricultural, forestry and fisheries establishments which use gas.
Residential	Private dwellings, including apartments which use fuel for heating, cooking, water heating, and other household uses.
Pipelines	Transportation of natural gas by compression through pipelines. Internal combustion engines and turbines are used to compress the gas.
Highway Vehicles	Automobile, light duty trucks and motorcycles which require gasoline and trucks, buses and automobiles which require diesel fuel and are used in transportation or public roads.
Railroads	Trains, operated railroad equipment, space heating of buildings, and other related operations.
Coke Plants	Furnace and merchant plants which produce coke.
Copper Smelters	Primary copper smelting facilities.
Vessels	Commercial or private boats, such as pleasure craft, fishing boats, tugboats and ocean-going vessels including vessels operated by oil companies.
Off Highway Diesel	Engines used in construction, logging and road building equipment.
Cement Plants	Portland cement manufacturing plants

TABLE 3. SOURCES OF STATE LEVEL FUEL CONSUMPTION DATA, 1950-1980

Source Category	Reference Numbers							
	1950	1955	1960	1965	1970	1975	1978	1980
Bituminous Coal								
Electric Utilities	14	23	10[a]	10[a]	3[b]	4[b]	11[b]	26[b]
Industrial Boilers	15[b],31	15[b]	10[a]	10[a]	3[b]	4[b]	11[b]	26[b]
Commercial-Residential	15[b],31	15[b]	10[a]	10[a]	3[b]	4[b]	11[b]	26[b]
Anthracite Coal								
Total Shipments	5	1	10	10	27	27	27,28	26
Residual Oil								
Electric Utilities	17[c]	17[c]	9[a]	9[a]	7[c]	7[c]	12[c]	24[d]
Industrial Boilers	17[c]	17[c]	9[a]	9[a]	7[c]	7[c]	12[c]	24[d]
Commercial-Residential	17[c]	17[c]	9[a]	9[a]	7[c]	7[c]	12[c]	24[d]
Distillate Oil								
Electric Utilities	16[c]	16[c]	9[a]	9[a]	7[c]	7[c]	12[c]	24[d]
Industrial Boilers	16[c]	16[c]	9[a]	9[a]	7[c]	7[c]	12[c]	24[d]
Commercial-Residential	16[c]	16[c]	9[a]	9[a]	7[c]	7[c]	12[c]	24[d]
Natural Gas								
Electric Utilities	2	1	8[a]	8[a]	6	6	13	25
Industrial	2	1	8[a]	8[a]	6	6	13	25
Pipelines	2	1	8[a]	8[a]	6	6	13	25
Commercial-Residential	2	1	8[a]	8[a]	6	6	13	25
Wood								
All Uses	32	32	32	32	32	32	32	32
Highway Vehicles								
Gasoline	22	22	22	22	—	—	—	—
Diesel	16,17	16,17	16,17	16,17	7[c]	7[c]	12[c]	24[d]
Rural VMT[c]	—	—	—	—	18	19	20	21
Urban VMT[e]	—	—	—	—	18	19	20	21
Other								
Railroads - Coal	39	39	39	39	39	39	39	39
- Oil	16,17	16,17	16,17	16,17	7[c]	7[c]	12[c]	24[d]
Coke Plants	29	30	10[a]	10[a]	3[b]	4[b]	11[b]	25[d]
Vessels - Distillate	16[c]	16[c]	16[c]	16[c]	7[c]	7[c]	12[c]	24[d]
- Residual	17[c]	17[c]	17[c]	17[c]	7[c]	7[d]	12[c]	24[d]
Off-Highway Diesel	16,17[c]	16[c]	16[c]	16[c]	7[c]	7[c]	12[c]	24[d]
Cement Plants	34	34	34	34,36	34,35	34,35	34,35	34,35

[a] Reports annual fuel demand.

[b] Reports annual fuel distribution.

[c] Reports annual sales.

[d] Reports annual fuel deliveries.

[e] Vehicle miles traveled.

TABLE 4. FOOTNOTES TO FUEL CONSUMPTION DATA

Source Category	Footnote							
	1950	1955	1960	1965	1970	1975	1978	1980
Bituminous Coal								
Electric Utilities					l	l		
Industrial Boilers	s	i			l	l		
Commercial-Residential	s	i			l	l		
Residual Oil [f]								
Electric Utilities								
Industrial Boilers	d	d			d	d	d	d
Commercial-Residential	j	j			c	c	c	c
Distillate Oil [b,f]								
Electric Utilities								
Industrial Boilers	d	d			d	d	d	d
Commercial-Residential	j,r	j,r			c,q,r	c,q,r	c,q,r	c,q
Natural Gas								
Electric Utilities	o	o						
Industrial	k,p	k,p			e,n,p	e,n,p	e	e
Pipelines			g	g				
Commercial-Residential					a,m	a,m	a,m	a,m
Wood	t	t						
Highway Vehicles - Diesel					h			
Off-Highway Diesel	u				h			

[a] Includes gas delivered to municipalities and Government agencies for use in schools, institutions, street lighting, etc.

[b] Includes No. 1 and No. 2 distillate oil and kerosene.

[c] Includes fuel for operating machinery, space heating, fueling of vessels and trucks, and other operations by the U.S. Armed Forces.

[d] Includes oil company use for the operation of drilling equipment, other field or refinery operations, and space heating at petroleum refineries, pipeline companies, and oil-drilling companies.

[e] Does not include natural gas used in lease operations as gas processing plant fuel, and not used for gas lift.

[f] Does not include fueling of commercial or private boats, such as pleasure craft, fishing boats, tugboats and ocean-going vessels.

[g] The fuel consumption reported in Reference 8 for the sector entitled, "Transportation" was used for the pipeline category.

[h] Values shown are for the year 1971.

[i] Values shown are for the year 1954.

[j] The distillate and residual oil sales for 1950 and 1955 was calculated as follows:
Distillate = Kerosene heating + Military + Miscellaneous
Residual = Military + Miscellaneous

[k] Calculated by subtracting the fuel consumption reported for pipelines from the fuel consumption reported for total industrial to avoid double counting of pipelines.

[l] From References 3 and 4, the category "Retail Dealers" was assumed to be commercial and "All Others (which exclude vessel fuel and bunker fuel)" was assumed to be industrial.

[m] Includes "other consumers".

TABLE 4. FOOTNOTES TO FUEL CONSUMPTION DATA (concluded)

[n] Includes natural gas used by petroleum refineries and for carbon black production.

[o] Includes some manufactured gas.

[p] Includes natural gas used in portland cement plants, carbon black manufacture and petroleum refineries.

[q] Includes consumption reported for commercial-residential sector, military (No. 1 and No. 2 distillate), and commercial-residential (kerosene).

[r] Includes kerosene used for space heating for industrial operations.

[s] Estimated by using following ratio:

$$\text{State Industrial}_{1950} = \frac{\text{National Consumption 1955}}{\text{National Consumption 1950}} \times \text{State Industrial 1955}$$

The same ratio was used for commercial-residential source category.

[t] Based on the ratio of national U.S. wood consumption in 1950 and 1955 to the national consumption in 1960 as follows:

$$\text{State 1955} = \frac{\text{National Consumption 1955}}{\text{National Consumption 1960}} \times \text{State 1960}$$

[u] Based on 1953 diesel oil consumption data.

TABLE 5. SOURCES OF STATE LEVEL FUEL CONSUMPTION DATA, 1900-1945

	Reference Numbers									
Source Category	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
Bituminous Coal										
All categories	37	37	37	37	37	37	37	37	37	37
Anthracite	NA	NA	NA	38	NA	NA	NA	NA	39	40
Residual Oil										
All categories	NA	NA	NA	NA	NA	NA	NA	17	17	17
Distillate Oil										
All categories	NA	NA	NA	NA	NA	NA	NA	16	16	16
Natural Gas										
Electric Utilities	NA	NA	NA	NA	NA	NA	48	NA	42	43
Industrial	NA	NA	44	45	46	47	48	NA	42	43
Commercial-Residential	NA	NA	44	45	46	47	41	NA	49	50
Highway Vehicles										
Gasoline	NA	NA	NA	NA	22	22	22	22	22	22
Diesel	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Miscellaneous										
Railroad - Coal	37	37	37	37	37	37	37	37	37	37
- Oil	NA	NA	NA	NA	NA	NA	NA	16	16	16
Coke Plants	37	37	37	37	37	37	37	37	37	37
Vessels - Oil	NA	NA	NA	NA	NA	NA	NA	16	16	16
Cement Plants	51	52	53	54	55	56	57	58	59	60

NA = Not Available.

intervening study years. These fractions were used to apportion the yearly total coal consumption by each category to the states for each study year.

The method of apportionment was used for the other fuels and associated source categories when state level data were not available. Table 6 shows the national fuel consumption for each category. Where national data are not available, state level data could not be estimated. In these cases, the emissions are marked "NA." For all fuels except coal, the benchmark years coincided with the study years with few exceptions which are noted in the tables.

SULFUR CONTENT DATA

Average sulfur content of the coal and fuel oil consumed in each state was obtained from various publications identified in Table 7. The earliest year of published data was 1965 for coal and 1955 for fuel oil. The average statewide sulfur content of coal was estimated for 1955 by relating the average sulfur reported by mining seam in the state or origin with eventual destination and end use. The results of this laborious method compared extremely well with the published data for 1955. Special footnotes to the sulfur data are listed in Table 8 according to each source category.

Fuel sulfur content data are presented in Appendix A for each source category by state and by year.

EMISSION FACTORS

Since no basis could be found for applying a different emission factor for each year, the factors were kept constant. For each source category, an average emission factor was calculated based on the latest factors published by EPA.[79,80] These factors, shown in Table 9, were weighted by the quantity of fuel consumed by each boiler or engine type used within each source category definition to yield an average weighted emission factor for each category. The quantity of fuel consumed by the various boiler types (i.e., tangentially fired, horizontally opposed, cyclone etc.) was obtained from the EPA National Emission Data System.

The emission factors for highway vehicles are presented in Appendix B. The NO_x emission factors are adjusted to account for rural and urban

TABLE 6. NATIONAL FUEL CONSUMPTION BY SOURCE CATEGORY, 1900-1950

Source Category	CONSUMPTION (1,000 Tons)									
	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
Bituminous Coal [a] (1,000 tons)										
Electric Utilities	7,600	14,540	19,798	26,527	33,411	42,541	42,900	30,937	49,126	71,610
Industrial Boilers	67,200	101,790	127,419	153,907	161,827	168,818	141,830	114,637	127,595	145,007
Commercial-Residential	28,100	44,061	57,582	75,965	79,701	90,911	98,563	80,442	84,685	119,300
Anthracite Coal [b] (1,000 tons)	55,515	75,201	81,110	86,033	85,786	64,061	67,628	51,100	49,000	51,600
Residual Oil [c] (1,000 bbl)										
Electric Utilities	NA	NA	NA	NA	NA	33,652	26,749	23,647	31,164	38,289
Industrial Boilers	NA	NA	NA	NA	NA	118,037	112,816	111,692	123,688	162,457
Commercial-Residential	NA	NA	NA	NA	NA	36,835	62,572	100,414	191,153	290,892
Distillate Oil [c] (1,000 bbl)										
Electric Utilities	NA	NA	NA	NA	NA	33,652	26,749	23,647	31,164	38,289
Industrial Boilers	NA	NA	NA	NA	NA	118,037	112,816	111,692	123,688	162,457
Commercial-Residential	NA	NA	NA	NA	NA	36,835	62,572	100,414	191,153	290,892
Natural Gas [a] (10^6 cu.ft.)										
Electric Utilities	NA	NA	NA	NA	22,000	46,000	120,000	125,239	183,156	326,190
Industrial [d]	NA	NA	339,332	412,000	512,000	916,293	NA	1,227,880	1,893,213	3,062,980
Pipelines	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Commercial-Residential	NA	NA	169,823	217,203	286,001	272,146	376,407	310,200	578,290	837,499
Highway Vehicles [e] Motor Fuel (1,000 gal)	NA	NA	NA	NA	NA	8,749	14,754	16,345	22,001	19,149
Wood [b] All uses combined (1,000 tons)	100,00	95,000	91,000	87,000	83,000	79,000	75,000	72,000	70,000	65,000
Other										
Railroads - Coal [a] (1,000 tons)	57,200	91,760	115,282	129,037	142,779	118,455	101,899	79,790	88,122	128,317
- Oil [c] (1,000 bbl)	NA	NA	NA	NA	NA	72,218	67,900	55,651	66,260	114,719
Coke Plants [a]	30,201	41,082	57,841	62,239	75,922	69,860	69,805	50,514	81,384	95,348
Vessels - Oil [c] (1,000 bbl)	NA	NA	NA	NA	NA	79,288	94,131	74,581	61,824	101,121

[a] Reference Mines, Mineral Yearbooks and Geological Survey, Resources of the U.S.

[b] Reference 77, p. 508-509.

[c] Reference 77, p. 113. Includes residual, distillate, and gas oil but excludes diesel oil and kerosene sold as range oil.

[d] Includes petroleum refineries, portland cement plants and "other industrial uses."

[e] Reference 22.

TABLE 7. SOURCES OF SULFUR CONTENT DATA

Source Category	Reference Numbers							
	1950	1955	1960	1965	1970	1975	1978	1980
Bituminous Coal								
Electric Utilities	a	75,76	c	63	62	62	62	61
Industrial Boilers	a	75,76	c	63	68,69	66,67	66,11	66,11
Commercial-Residential	a	75,76	c	63	68,69	66,67	66,11	66,11
Residual Oil								
Electric Utilities	b	b	b	62	62	62	62	61
Industrial Boilers	a	70	71	72	64	65	73	74
Commercial-Residential	a	70	71	72	64	65	73	74
Distillate Oil								
Electric Utilities	-	-	-	-	-	-	-	-
Industrial Boilers	a	70	71	72	64	65	73	74
Commercial-Residential	a	70	71	72	64	65	73	74
Coke Plants	a	75,76	c	63	68,69	66,67	66,71	56

[a] Same references and data were used as for 1955.

[b] Same reference and data were used as for 1970.

[c] Same reference and data were used as for 1965.

TABLE 8. FOOTNOTES TO SULFUR CONTENT DATA

Source Category	Footnote							
	1950	1955	1960	1965	1970	1975	1978	1980
Bituminous Coal								
Electric Utilities	m	p		f,k				d
Industrial Boilers	m	p		j,k	h,l	g	a	i
Commercial-Residential	m	p		j,k	h,l	g	a	i
Residual Oil								
Electric Utilities	n	n	n	n	e	e		c,e
Industrial Boilers	m	b	b	b	b	b	b	b
Commercial-Residential	m	b	b	b	b	b	b	b
Distillate Oil								
Electric Utilities								
Industrial	m	b	b	b	b	b	b	b
Commercial-Residential	m	b	b	b	b	b	b	b
Coke Plants	m		o	k	h,l	g	a	i

[a] Calculated a weighted average sulfur content based on the average sulfur content by consumer use and district of origin Reference 66, p. 20, Table 4 and the coal distribution data, Reference 11, p. 29-72, Table III.

[b] Average sulfur content was given by marketing districts. The states contained within each district were assigned the average for the district. Those states which overlapped districts were approximately divided according to the area in each district. The average sulfur content was established by weighing the sulfur content of each district according to the area of the state in each district.

[c] Based on fuel oil receipts.

[d] Based on coal receipts.

[e] Sulfur content for residual and distillate oil are combined in one category.

[f] The percent sulfur for electric utilities was adjusted by adding 0.3 percent to each number to account for the use of raw coal. See reference 63, p. 14 for explanation.

[g] Calculated a weighted average sulfur content based on the average sulfur content reported by consumer use and district of origin, Reference 66, p. 17, Table 4 and the coal distribution data, Reference 67, p. 8-41, Table 1.

[h] Calculated weighted average sulfur content based on the average sulfur content by consumer use and district of origin, Reference 69, p. 384, Table 41 and the coal distribution data, Reference 68, p. 8-31, Table I.

[i] Since 1980 data was unavailable for industrial, commercial-residential, and coke plant data, 1978 data was used instead.

[j] Percent sulfur content for industrial and commercial-residential was calculated for each state as follows based on Reference 63, p. 17:

$$\%S = \frac{1.1 + \%\ S\ \text{utility}}{2}$$

[k] Data reported for 1964 is used for 1965.

[l] Average sulfur content was reported by state of origin in Reference 69. The average sulfur content was assigned to each state within the district in which it was used according to Reference 68.

[m] Same data used as for 1955.

[n] Same data used as for 1970.

[o] Same data used as for 1965.

[p] Estimated by determining the weighted sulfur content by mine according to the average sulfur content reported by seam in Reference 75. If several coal analyses were reported for one seam, the sulfur content values were averaged. The average sulfur content for all mines in a state was weighted according to the mine production reported in Reference 75. The average statewide sulfur content was then apportioned to consumer uses and final destination according to Reference 76.

TABLE 9. EMISSION FACTORS[a]

Source Category	SO_2	NO_x
Bituminous Coal (lb/ton)		
Electric Utilities	39 S[b,c]	23[d]
Industrial Boilers	38.5 S[b]	19[d]
Commercial-Residential	36 S[b]	12[d]
Anthracite Coal (lb/ton)		
All uses	39 S	16.5
Residual Oil (lb/bbl)		
Electric Utilities	6.594 S	2.4
Industrial Boilers	6.594 S	2.31
Commercial-Residential	6.594 S	2.31
Distillate Oil (lb/bbl)		
Electric Utilities	5.964 S	0.84
Industrial Boilers	5.963 S	0.84
Commercial-Residential	5.364 S	0.80
Natural Gas [i] (lb/10^6 cu.ft.)		
Electric Utilities	0.6	490
Industrial	0.6	140
Pipelines	0.6	2,400[h]
Commercial-Residential	0.6	100
Wood [e] (lb/ton)		
Electric Utilities	0.148	2.8
Industrial	0.148	1.5
Commercial	0.20	1.5
Residential	0.40	3.1
Highway Vehicles		
Gasoline	[f]	[f]
Diesel (lb/gal.)	0.0346	0.2927
Other		
Railroads - Coal (lb/ton)	39	7.5
- Dist. (lb/bbl)	2.394	15.54
Coke Plants (lb/ton coal)	5.025	0.04
Vessels [g] - Dist. (lb/bbl)	1.26	9.408
- Res. (lb/bbl)	10.685	1.75
Off Highway Diesel (lb/bb)	1.302	15.36
Cement Plants (lb/ton cement)	[f]	2.6

[a] Factors represent uncontrolled emissions and are applied to fuel consumption as fired.

[b] Expressed as SO_2, including SO_2, SO_3 and gaseous sulfates. On average 97 percent of the fuel sulfur is emitted as SO_2, where as only about 0.7 percent of the fuel sulfur is emitted as SO_3 and gaseous sulfate. For Texas, North Dakota and Minnesota emission factors for lignite combustion are used. These are 30.0 lb of SO_2/ton for all categories, 14.0 lb of NO_x/ton for electric utilities, 10.2 lb of NO_x/ton for industrial boilers, and 6.8 lb of NO_x/ton for commercial-residential categories.

[c] S is the percent sulfur content of the fuel expressed as percent sulfur by weight.

[d] Expressed as NO_2. Generally, 95-98 percent volume of the nitrogen oxide present in combustion exhaust is in the form of NO. The rest is NO_2.

[e] For 1900 to 1945, 0.2 lb of SO_2/ton and 1.5 lb of NO_x/ton are used for all categories.

[f] See Appendix A.

[g] For 1900 to 1945, 10 lb of SO_2/ton and 1.75 lb of NO_x/ton are used irrespective of the type of fuel oil.

[h] Calculated by weighting the emission factor for reciprocating engines and for gas turbines according to the 1980 fuel consumption reported in NEDS. The factor for reciprocating engines assumes a heating value of 1,050 Btu/scf for natural gas and an average fuel consumption of 7,500 Btu/hp-hr.

[i] Factors are based on an average sulfur content of natural gas of 4,000 g/10^6 m^3 (2,000 gr/10^6 scf).

traffic and average state altitude. For years 1970 to 1980, these factors are based on the vehicle miles traveled (VMT). For earlier years, the factors were based on actual fuel consumption according to the average fuel efficiencies shown in Table 10.

Table 10. HISTORIC FUEL EFFICIENCIES OF HIGHWAY VEHICLES,[a]

Year	Miles per gallon
1936	13.98
1940	13.83
1950	12.87
1960	12.44
1965	12.48

[a]Reference 22.

CALCULATIONS

For each pollutant, the fuel consumption matrix (FC) was multiplied by the appropriate emission factor (EF). For SO_2, the emission factor included the sulfur content matrix(S). The calculation is expressed as follows:

$$\text{Emissions}_{i,j,k} = FC_{i,j,k} \times [S_{i,j,k} \times EF]$$

where, i = year
j = source category
k = state

The resulting emission estimates represent uncontrolled emissions except for highway vehicles where the emission factor accounts for the effect of emission control devices since 1965. For the electric utilities category, the quantity of SO_2 emission reductions due to flue gas desulfurization (FGD) systems was subtracted from the estimates. The amount of reductions for each state is shown in Table 11. The data were compiled from individual power plant data provided in reference 78. The first study year during which FGD systems actually reduced SO_2 emissions was 1975 although these systems reduced emissions as early as 1971 in some states. For all previous years, emission estimates based on uncontrolled emission factors essentially represent actual emissions.

TABLE 11. POWER PLANT EMISSION REDUCTIONS[a]

State	Emission Reductions (1,000 tons)		
	1975	1978	1980
Alabama	0	2.2	9.8
Arizona	2.4	5.6	33.7
Colorado	0	0	6.5
Illinois	0	12.9	148.1
Indiana	0	54.7	95.0
Kansas	103.9	68.6	78.1
Kentucky	1.4	36.5	169.7
Minnesota	0	32.4	49.4
Mississippi	0	2.2	12.8
Missouri	7.7	25.1	36.6
Montana	1.4	17.6	20.6
Nevada	5.0	9.5	8.2
New Mexico	0	14.7	42.0
North Dakota	0	10.5	26.3
Ohio	0	89.6	113.6
Pennsylvania	40.7	213.1	325.9
South Carolina	0	6.5	13.6
Texas	0	64.6	134.5
Tennessee	0	34.0	24.0
Utah	0	4.5	23.3
West Virginia	0	0	5.2
Wyoming	0	0	13.1
Total	162.5	704.9	1,390.0

[a] Data extracted from Reference 78 by Charles O. Mann, National Air Data Branch, U.S. Environmental Protection Agency.

SECTION 3

RESULTS

For each state, there are ten tables and four figures that show all the results. The states are presented in alphabetical order. The tables and figures for each state appear in the following order.

Fuel Consumption Data
- Table 1. Fuel Consumption 1900-1945 for the State
- Table 2. Fuel Consumption 1950-1980 for the State

Sulfur Dioxide Emissions Data
- Table 3. SO_2 Emissions 1900-1945
- Table 4. SO_2 Emissions 1950-1980
- Table 5. Summary of SO_2 Emissions by Source Category
- Table 6. Summary of SO_2 Emissions by Fuel Type
- Figure 1. Historic Trend in SO_2 Emissions by Source Category
- Figure 2. Historic Trend in SO_2 Emissions by Fuel Type

Nitrogen Oxide Emissions Data
- Table 7. NO_x Emissions 1900-1945
- Table 8. NO_x Emissions 1950-1980
- Table 9. Summary of NO_x Emissions by Source Category
- Table 10. Summary of SO_2 Emissions by Fuel Type
- Figure 3. Historic Trend in NO_x Emissions by Source Category
- Figure 4. Historic Trend in NO_x Emissions by Fuel Type

While the tables present the estimated emissions for all the years, the figures show only the emissions from 1950 to 1980. This is because the estimates for the last thirty years are consistent and complete while the estimates for earlier years are comparatively incomplete. To avoid misinterpretation of the trend, only the data for the latter years is shown. At the end of the results for the states, the total SO_2 and NO_x emissions are summarized.

TABLE 1. FUEL CONSUMPTION 1900-1945 FOR THE STATE OF ALABAMA

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL(1000 TONS)										
ELECTRIC UTILITIES	83.	138.	189.	252.	303.	356.	424.	398.	780.	1351.
INDUSTRIAL BOILERS	981.	1404.	1821.	2262.	2392.	2473.	1964.	1446.	1451.	1467.
COMMERCIAL-RESIDENTIAL	306.	457.	624.	856.	913.	1041.	1086.	829.	810.	1056.
ANTHRACITE COAL (1000 TONS)										
ALL USES	5.	7.	8.	8.	8.	6.	NA	NA	NA	NA
RESIDUAL OIL (1000 BBL)										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	20.	16.	14.	34.	16.
INDUSTRIAL	NA	NA	NA	NA	NA	120.	115.	114.	171.	727.
COMMERCIAL	NA	NA	NA	NA	NA	25.	42.	67.	114.	170.
DISTILLATE OIL (1000 BBL)										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	1.	1.	1.	5.	54.
INDUSTRIAL	NA	NA	NA	NA	NA	45.	43.	43.	64.	187.
COMMERCIAL -RESIDENTIAL	NA	NA	NA	NA	NA	46.	78.	125.	244.	621.
NATURAL GAS (10E6 CU. FT.)										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	NA	NA	624.	913.	6557.
INDUSTRIAL	NA	NA	NA	184.	0.	0.	732.	12888.	19872.	38714.
PIPELINES	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
COMMERCIAL-RESIDENTIAL	NA	NA	NA	0.	0.	0.	423.	1425.	2656.	4703.
WOOD (1000 TONS)										
ALL USES	5225.	4964.	4755.	4546.	4337.	4128.	3919.	3762.	3658.	3396.
HIGHWAY VEHICLES										
GASOLINE(1000 GAL)	NA	NA	NA	NA	NA	101986.	164428.	166013.	250234.	274086.
DIESEL (1000 GAL.)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MISCELLANEOUS										
RAILROADS-COAL(1000 TONS)	888.	1322.	1698.	1943.	2247.	1972.	1789.	1474.	1699.	2569.
RAILROADS-OIL(1000 BBL)	NA	NA	NA	NA	NA	132.	124.	102.	119.	390.
COKE PL (1000 TONS COAL)	3202.	4054.	5527.	5754.	6809.	6088.	5734.	3815.	5607.	5938.
VES FUEL OIL (1000 BBL)	NA	NA	NA	NA	NA	1513.	1796.	1423.	1195.	2153.
CEMENT PL (1000 TONS)	0.	NA	NA	NA	NA	1182.	906.	469.	962.	1042.

TABLE 2. FUEL CONSUMPTION 1950-1980 FOR THE STATE OF ALABAMA

SOURCE CATEGORY	1950	1955	1960	1965	1970	1975	1978	1980
BITUMINOUS COAL(1000 TONS)								
ELECTRIC UTILITIES	1006.	4917.	7264.	12572.	15759.*	19246.	13782.	18383.
INDUSTRIAL BOILERS	923.	863.*	7008.	9512.	2265.*	2163.	3130.	2375.
COMMERCIAL-RESIDENTIAL	756.	476.*	274.	99.	150.*	13.	46.	209.
ANTHRACITE COAL (1000 TONS)								
ALL USES	0.	0.	24.	38.	0.	0.	0.	47.
RESIDUAL OIL (1000 BBL)								
ELECTRIC UTILITIES	0.	0.	0.	0.	0.	0.	0.	0.
INDUSTRIAL	998.	1285.	1758.	726.	1431.	2708.	5802.	3774.
COMMERCIAL	61.	113.	142.	80.	215.	3393.	3572.	589.
DISTILLATE OIL (1000 BBL)								
ELECTRIC UTILITIES	7.	65.	0.	0.	38.	651.	1141.	128.
INDUSTRIAL	935.	824.	1388.	684.	1080.	1358.	1763.	1522.
COMMERCIAL-RESIDENTIAL	989.	1724.	1016.	1083.	1651.	3656.	4653.	1127.
NATURAL GAS (10E6 CU. FT.)								
ELECTRIC UTILITIES	16396.	17414.	9378.	4706.	15444.	5994.	7015.	1382.
INDUSTRIAL	74265.	108659.	110711.	135341.	170937.	153540.	129427.	160552.
PIPELINES	2373.	6326.	7600.	11998.	20083.	18801.	14210.	26447.
COMMERCIAL-RESIDENTIAL	15828.	36340.	58322.	80045.	92033.	85753.	86606.	80059.
WOOD (1000 TONS)								
ELECTRIC UTILITIES	0.	0.	0.	0.	0.	0.	0.	0.
INDUSTRIAL	1074.	1274.	1372.	1864.	2435.	2722.	3186.	3218.
COMMERCIAL	39.	30.	24.	17.	11.	12.	13.	13.
RESIDENTIAL	2022.	1558.	1260.	809.	599.	616.	671.	705.
HIGHWAY VEHICLES								
GASOLINE (1000 GAL.)	526142.	773575.	1004290.	1248551.	NA	NA	NA	NA
DIESEL (1000 GAL.)	10584.	13062.	25536.	49728.	120540.	182994.	263970.	317948.
RURAL VMT (10E6 MILES)	NA	NA	NA	NA	10229.	12328.	16081.	15523.
URBAN VMT (10E6 MILES)	NA	NA	NA	NA	7342.	12510.	13826.	13504.
MISCELLANEOUS								
RAILROADS-COAL(1000 TONS)	1411.	439.	89.	0.	0.	0.	0.	0.
-OIL(1000 BBL)	640.	1163.	1459.	1597.	2009.	2723.	2841.	2955.
COKE PLANTS (1000 TONS COAL)	8221.	8540.	6719.	7219.	8533.*	6783.	4656.	5013.
VESSELS-DISTILLATE(1000 BBL)	51.	78.	64.	14.	91.	194.	319.	93.
-RESIDUAL(1000 BBL)	255.	597.	522.	289.	385.	1653.	1704.	732.
OFF HIGHWAY DIESEL (1000 BBL)	290.	282.	1001.	614.	1368.	1246.	2805.	676.
CEMENT PLANT (1000 TONS)	1950.	2286.	2244.	2649.	2405.	1995.	2955.	2520.

* Calculated by apportioning the fuel consumption reported for a group of states to the individual state based on the data for the following year.

TABLE 3. SO2 EMISSIONS (1000 TONS) 1900-1945 ALABAMA

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL										
ELECTRIC UTILITIES	3.5	5.7	7.9	10.5	12.6	14.8	17.6	16.5	32.4	56.1
INDUSTRIAL BOILERS	30.4	43.5	56.4	70.1	74.1	76.7	60.9	44.8	45.0	45.6
COMMERCIAL-RESIDENTIAL	9.0	13.5	18.4	25.1	26.9	30.7	32.1	24.5	23.9	31.2
ANTHRACITE COAL										
ALL USES	.1	.1	.1	.1	.1	.1	NA	NA	NA	NA
RESIDUAL OIL										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	.0	.0	.0	.0	.0
INDUSTRIAL	NA	NA	NA	NA	NA	.6	.6	.6	.9	3.7
COMMERCIAL	NA	NA	NA	NA	NA	.1	.2	.3	.6	.9
DISTILLATE OIL										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	.0	.0	.0	.0	.0
INDUSTRIAL	NA	NA	NA	NA	NA	.0	.0	.0	.1	.2
COMMERCIAL-RESIDENTIAL	NA	NA	NA	NA	NA	.0	.1	.1	.2	.6
NATURAL GAS										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	NA	NA	.0	.0	.0
INDUSTRIAL	NA	NA	NA	.0	.0	.0	.0	.0	.0	.0
PIPELINES	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
COMMERCIAL-RESIDENTIAL	NA	NA	NA	.0	.0	.0	.0	.0	.0	.0
WOOD										
ALL USES	.5	.5	.5	.5	.4	.4	.4	.4	.4	.3
HIGHWAY VEHICLES										
GASOLINE	NA	NA	NA	NA	NA	.0	.0	.0	.0	.0
DIESEL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MISCELLANEOUS										
RAILROADS-COAL	27.9	41.5	53.3	61.0	70.6	62.9	56.2	46.3	53.3	80.6
-OIL	NA	NA	NA	NA	NA	.2	.1	.1	.1	.5
COKE PLANTS	.1	.1	.1	.2	.2	.2	.2	.1	.2	.2
VESSELS FUEL OIL	NA	NA	NA	NA	NA	7.6	9.0	7.1	6.0	10.0
CEMENT PLANTS	.0	NA	NA	NA	NA	8.5	6.5	3.4	6.9	7.5

TABLE 4. SO2 EMISSIONS (1000 TONS) 1950-1980 ALABAMA

SOURCE CATEGORY	1950	1955	1960	1965	1970	1975	1978	1980
BITUMINOUS COAL								
ELECTRIC UTILITIES	41.8	204.2	311.6	539.3	758.1	804.6	491.2	560.2
INDUSTRIAL BOILERS	28.6	26.7	222.6	302.1	52.3	77.4	111.4	84.5
COMMERCIAL-RESIDENTIAL	22.3	14.1	8.1	2.9	3.2	.4	1.1	4.9
ANTHRACITE COAL								
ALL USES	.0	.0	.4	.6	.0	.0	.0	.7
RESIDUAL OIL								
ELECTRIC UTILITIES	.0	.0	.0	.0	.0	.0	NA	.0
INDUSTRIAL	5.1	6.6	8.7	3.9	8.2	16.7	32.5	23.9
COMMERCIAL	.3	.6	.7	.4	1.2	20.9	20.0	3.7
DISTILLATE OIL								
ELECTRIC UTILITIES	.0	.0	.0	.0	.0	.3	.5	.1
INDUSTRIAL	.9	.8	1.0	.3	.6	.8	1.0	1.0
COMMERCIAL-RESIDENTIAL	1.0	1.7	.8	.5	.8	2.1	2.7	.7
NATURAL GAS								
ELECTRIC UTILITIES	.0	.0	.0	.0	.0	.0	.0	.0
INDUSTRIAL	.0	.0	.0	.0	.1	.0	.0	.0
PIPELINES	.0	.0	.0	.0	.0	.0	.0	.0
COMMERCIAL-RESIDENTIAL	.0	.0	.0	.0	.0	.0	.0	.0
WOOD								
ELECTRIC UTILITIES	.0	.0	.0	.0	.0	.0	.0	.0
INDUSTRIAL	.1	.1	.1	.1	.2	.2	.2	.2
COMMERCIAL	.0	.0	.0	.0	.0	.0	.0	.0
RESIDENTIAL	.4	.3	.3	.2	.1	.1	.1	.1
HIGHWAY VEHICLES								
GASOLINE	1.3	1.8	2.1	2.6	2.8	3.9	4.8	4.7
DIESEL	.2	.2	.4	.9	2.1	3.2	4.6	5.5
MISCELLANEOUS								
RAILROADS-COAL	44.3	13.8	2.9	.0	.0	.0	.0	.0
-OIL	.8	1.4	1.7	1.9	2.4	3.3	3.4	3.5
COKE PLANTS	32.0	33.3	18.6	20.0	17.2	16.5	10.9	11.0
COPPER SMELTERS	.0	.0	.0	.0	.0	.0	.0	.0
VESSELS-DISTILLATE	.0	.0	.0	.0	.1	.1	.2	.1
-RESIDUAL	1.4	3.2	2.0	1.5	2.1	8.8	9.1	3.9
OFF HIGHWAY DIESEL	.2	.2	.7	.4	.9	.8	1.8	.4
CEMENT PLANT	14.0	16.4	16.1	19.2	16.5	15.1	20.5	17.7

TABLE 5. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR ALABAMA

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
ELECTRIC UTILITIES	3.5*	5.7*	7.9*	10.5*	12.6*	14.0*	17.6*	16.5	32.4	56.2
INDUSTRIAL	30.5*	43.6*	56.6*	70.3*	74.3*	86.0	68.2	48.9	53.0	57.0
COMMERCIAL-RESIDENTIAL	9.0*	13.5*	18.4*	25.3*	26.9*	30.9	32.4	24.9	24.8	32.7
PIPELINES	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*
HIGHWAY VEHICLES	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*
OTHER	28.5*	42.1*	52.9*	61.6*	71.1*	70.2	65.7*	53.9*	59.8*	92.2*
TOTAL	71.5	105.0	136.7	167.6	185.0	201.0	183.8	144.3	169.9	238.1

TABLE 5. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR ALABAMA

SOURCE CATEGORY	1950	1955	1960	1965	1970	1975	1978	1980
ELECTRIC UTILITIES	41.8	204.3	311.6	539.3	758.1	884.9	491.8*	560.2
INDUSTRIAL	80.8	84.0	267.2	345.7	94.9	126.7	176.6	139.1
COMMERCIAL - RESIDENTIAL	24.0	16.7	9.9	4.1	5.5	23.6	24.0	9.5
PIPELINES	.0	.0	.0	.0	.0	.0	.0	.0
HIGHWAY VEHICLES	1.5	2.0	2.5	3.4	4.9	7.1	9.3	10.2
OTHER	46.6	18.6	8.5	4.5	5.4	13.0	14.5	8.7
TOTAL	194.7	325.6	599.6	897.1	868.8	1055.3	716.3	727.7

*- MAY NOT INCLUDE ALL EMISSIONS BECAUSE DATUM WAS NOT AVAILABLE

TABLE 6. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY FUEL TYPE FOR ALABAMA

FUEL TYPE	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL	70.9	104.4	136.2	167.0	184.4	192.0	173.4	135.5	161.7	221.1
ANTHRACITE COAL	.1	.1	.1	.1	.1	.1	.0*	.0*	.0*	.0*
RESIDUAL OIL	.0*	.0*	.0*	.0*	.0*	8.3	9.8	8.0	7.4	15.3
DISTILLATE OIL	.0*	.0*	.0*	.0*	.0*	.3	.3	.3	.5	1.3
NATURAL GAS	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*
WOOD	.5	.5	.5	.5	.4	.4	.4	.4	.4	.3
GASOLINE, DIESEL	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*
TOTAL	71.5	105.0	136.7	167.6	185.0	201.0	183.8	144.3	169.9	238.1

TABLE 6. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY FUEL TYPE FOR ALABAMA

FUEL TYPE	1950	1955	1960	1965	1970	1975	1978	1980
BITUMINOUS COAL	183.0	308.5	579.9	883.5	847.3	994.0	635.1	679.0
ANTHRACITE COAL	.0	.0	.4	.6	.0	.0	.0	.7
RESIDUAL OIL	6.8	10.3	12.2	5.9	11.4	46.4	61.6*	31.5
DISTILLATE OIL	2.7	4.1	3.6	2.8	3.9	6.6	7.9	5.4
NATURAL GAS	.0	.1	.1	.1	.1	.1	.1	.1
WOOD	.5	.4	.4	.3	.3	.3	.4	.4
GASOLINE, DIESEL	1.6	2.2	3.1	3.0	5.8	7.9	11.1	10.6
OTHER(COPPER SMELTERS)	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	194.7	325.6	599.6	897.1	868.8	1055.3	716.3	727.7

*- MAY NOT INCLUDE ALL EMISSIONS BECAUSE DATUM WAS NOT AVAILABLE

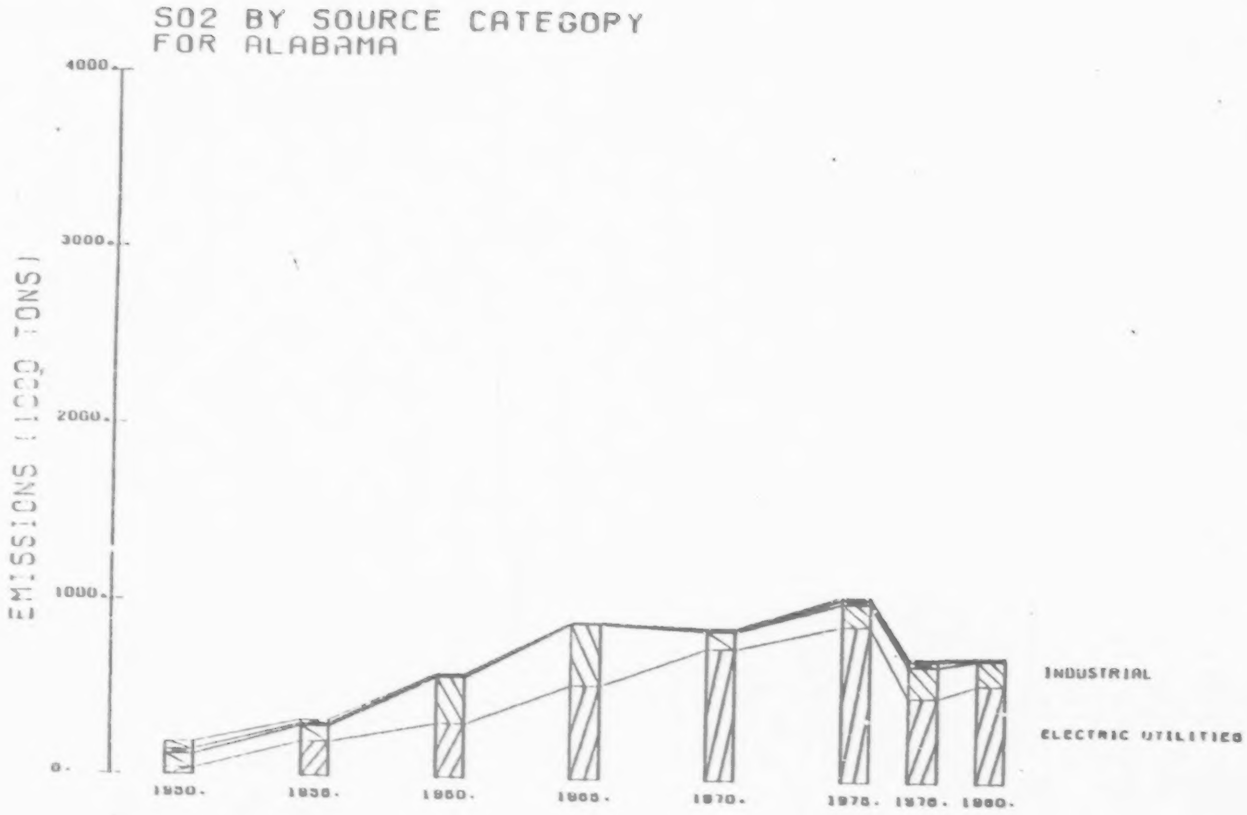


Figure 1. Historic trend in SO_2 emissions by source category.

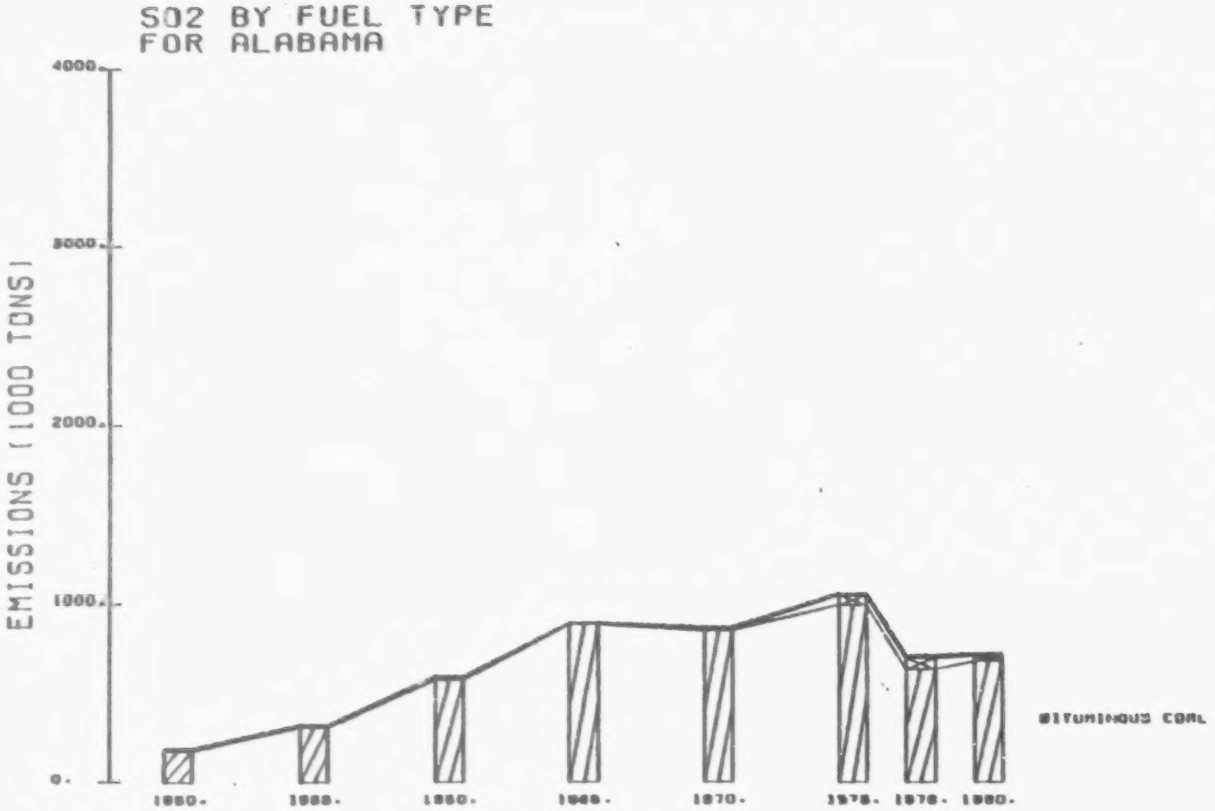


Figure 2. Historic trend in SO_2 emissions by fuel type.

TABLE 7. NOX EMISSIONS (1000 TONS) 1900-1945 ALABAMA

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL										
ELECTRIC UTILITIES	1.0	1.6	2.2	2.9	3.5	4.1	4.9	4.6	9.0	15.5
INDUSTRIAL BOILERS	9.3	13.3	17.3	21.5	22.7	23.5	18.7	13.7	13.8	13.9
COMMERCIAL-RESIDENTIAL	1.0	2.7	3.7	5.1	5.5	6.2	6.5	5.0	4.9	6.3
ANTHRACITE COAL										
ALL USES	.0	.1	.1	.1	.1	.1	NA	NA	NA	NA
RESIDUAL OIL										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	.0	.0	.0	.0	.0
INDUSTRIAL	NA	NA	NA	NA	NA	.1	.1	.1	.2	.8
COMMERCIAL	NA	NA	NA	NA	NA	.0	.0	.1	.1	.2
DISTILLATE OIL										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	.0	.0	.0	.0	.0
INDUSTRIAL	NA	NA	NA	NA	NA	.0	.0	.0	.0	.1
COMMERCIAL-RESIDENTIAL	NA	NA	NA	NA	NA	.0	.0	.0	.1	.2
NATURAL GAS										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	NA	NA	.2	.2	1.6
INDUSTRIAL	NA	NA	NA	.0	.0	.0	.1	.9	1.4	2.7
PIPELINES	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
COMMERCIAL-RESIDENTIAL	NA	NA	NA	.0	.0	.0	.0	.1	.1	.2
WOOD										
ALL USES	3.9	3.7	3.6	3.4	3.3	3.1	2.9	2.8	2.7	2.5
HIGHWAY VEHICLES										
GASOLINE	NA	NA	NA	NA	NA	12.6	20.3	20.5	30.0	33.8
DIESEL	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MISCELLANEOUS										
RAILROADS-COAL	3.3	5.0	6.4	7.3	8.4	7.4	6.7	5.5	6.4	9.6
-OIL	NA	NA	NA	NA	NA	1.0	1.0	.0	.9	3.0
COKE PLANTS	.5	.6	.8	.8	1.0	.9	.8	.6	.8	.9
VESSELS FUEL OIL	NA	NA	NA	NA	NA	1.3	1.6	1.2	1.0	1.9
CEMENT PLANTS	.0	NA	NA	NA	NA	1.5	1.2	.6	1.3	1.4

TABLE 8. NOX EMISSIONS (1000 TONS) 1950-1980 ALABAMA

SOURCE CATEGORY	1950	1955	1960	1965	1970	1975	1978	1980
BITUMINOUS COAL								
ELECTRIC UTILITIES	11.6	56.5	83.5	144.6	101.2	221.3	158.5	211.4
INDUSTRIAL BOILERS	8.8	0.2	66.6	90.4	21.5	20.5	29.7	22.6
COMMERCIAL-RESIDENTIAL	4.5	2.9	1.6	.6	.9	.1	.3	1.3
ANTHRACITE COAL								
ALL USES	.0	.0	.2	.3	.0	.0	.0	.4
RESIDUAL OIL								
ELECTRIC UTILITIES	.0	.0	.0	.0	.0	.0	.0	.0
INDUSTRIAL	1.2	1.5	2.0	.8	1.7	3.1	6.7	4.4
COMMERCIAL	.1	.1	.2	.1	.2	3.9	4.1	.7
DISTILLATE OIL								
ELECTRIC UTILITIES	.0	.0	.0	.3	.0	.3	.5	.1
INDUSTRIAL	.4	.3	.6	.3	.5	.6	.7	.6
COMMERCIAL-RESIDENTIAL	.4	.7	.4	.4	.7	1.5	1.9	.5
NATURAL GAS								
ELECTRIC UTILITIES	4.0	4.3	2.3	1.2	3.8	1.5	1.7	.3
INDUSTRIAL	5.2	7.6	7.7	9.5	12.0	10.7	9.1	11.2
PIPELINES	2.0	7.6	9.1	14.4	24.1	22.6	17.1	31.7
COMMERCIAL-RESIDENTIAL	.8	1.8	2.9	4.0	4.6	4.3	4.3	4.0
WOOD								
ELECTRIC UTILITIES	.0	.0	.0	.0	.0	.0	.0	.0
INDUSTRIAL	.8	1.0	1.0	1.4	1.8	2.0	2.4	2.4
COMMERCIAL	.0	.0	.0	.0	.0	.0	.0	.0
RESIDENTIAL	3.1	2.4	2.0	1.4	.9	1.0	1.0	1.1
HIGHWAY VEHICLES								
GASOLINE	34.0	48.0	60.2	74.8	83.9	115.5	125.0	110.2
DIESEL	1.5	1.9	3.7	7.3	17.6	26.8	38.6	46.5
MISCELLANEOUS								
RAILROADS-COAL	5.3	1.6	.3	.0	.0	.0	.0	.0
-OIL	5.0	9.0	11.3	12.4	15.6	21.2	22.1	23.0
COKE PLANTS	.2	.2	.1	.1	.2	.1	.1	.1
COPPER SMELTERS	.0	.0	.0	.0	.0	.0	.0	.0
VESSELS-DISTILLATE	.2	.4	.3	.1	.4	.9	1.5	.4
-RESIDUAL	.2	.5	.5	.3	.3	1.4	1.5	.6
OFF HIGHWAY DIESEL	2.3	2.3	8.0	4.9	10.9	9.9	22.4	5.4
CEMENT PLANT	2.5	3.0	2.9	3.4	3.1	2.6	3.8	3.3

TABLE 9. SUMMARY OF NOX EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR ALABAMA

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
ELECTRIC UTILITIES	1.0*	1.6*	2.2*	2.9*	3.5*	4.1*	4.9*	4.7	9.2	17.2
INDUSTRIAL	9.8*	13.9*	18.1*	22.3*	23.7*	26.1	20.9	16.0	17.5	19.8
COMMERCIAL-RESIDENTIAL	1.8*	2.7*	3.7*	5.1*	5.5*	6.3	6.6	5.2	5.2	7.0
PIPELINES	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.0*
HIGHWAY VEHICLES	.0*	.0*	.0*	.0*	.0*	12.6*	20.3*	20.5*	30.8*	33.8*
OTHER	7.3*	8.7*	10.0*	10.8*	11.7*	12.9	12.2*	10.4*	11.1*	17.1*
TOTAL	19.9	27.0	34.0	41.1	44.4	61.9	64.8	56.7	73.8	94.9

*- MAY NOT INCLUDE ALL EMISSIONS BECAUSE DATUM WAS NOT AVAILABLE

TABLE 9. SUMMARY OF NOX EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR ARIZONA

SOURCE CATEGORY	1950	1955	1960	1965	1970	1975	1978	1980
ELECTRIC UTILITIES	3.4	5.9	13.1	12.9	20.0	56.2	105.8	157.5
INDUSTRIAL	4.3	5.2	3.0	5.9	6.4	7.6	11.5	11.5
COMMERCIAL - RESIDENTIAL	1.3	1.6	3.1	2.8	3.0	4.2	4.0	3.4
PIPELINES	3.7	10.3	19.1	21.6	28.7	20.5	18.2	25.6
HIGHWAY VEHICLES	15.6	21.9	32.7	41.7	72.9	93.1	107.2	102.1
OTHER	13.1	3.3	13.4	15.8	10.8	11.0	21.5	16.0
TOTAL	41.4	48.2	84.3	100.8	141.8	192.6	268.1	316.1

TABLE 10. SUMMARY OF NOX EMISSIONS (1000 TONS) BY FUEL TYPE FOR ALABAMA

FUEL TYPE	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL	15.9	23.2	30.4	37.7	41.1	43.7	30.8	30.0	36.1	47.7
ANTHRACITE COAL	.0	.1	.1	.1	.1	.1	.0*	.0*	.0*	.0*
RESIDUAL OIL	.0*	.0*	.0*	.0*	.0*	1.5	1.8	1.5	1.4	2.9
DISTILLATE OIL	.0*	.0*	.0*	.0*	.0*	1.1	1.0	.9	1.1	3.4
NATURAL GAS	.0*	.0*	.0*	.0*	.0*	.0*	.1*	1.1*	1.7*	4.6*
WOOD	3.9	3.7	3.6	3.4	3.3	3.1	2.9	2.8	2.7	2.5
GASOLINE, DIESEL	.0*	.0*	.0*	.0*	.0*	12.6*	20.3*	20.5*	30.8*	33.8*
TOTAL	19.9	27.0	34.0	41.1	44.4	61.9	64.8	56.7	73.8	94.9

*- MAY NOT INCLUDE ALL EMISSIONS BECAUSE DATUM WAS NOT AVAILABLE

TABLE 10. SUMMARY OF NOX EMISSIONS (1000 TONS) BY FUEL TYPE FOR ALABAMA

FUEL TYPE	1950	1955	1960	1965	1970	1975	1978	1980
BITUMINOUS COAL	32.9	72.4	155.1	239.1	206.9	244.7	192.4	238.6
ANTHRACITE COAL	.0	.0	.2	.3	.0	.0	.0	.4
RESIDUAL OIL	1.4	2.1	2.7	1.2	2.2	8.5	12.3	5.7
DISTILLATE OIL	6.0	10.5	12.6	13.2	17.2	24.4	26.7	24.5
NATURAL GAS	12.9	21.3	22.1	29.0	44.5	39.1	32.2	47.4
WOOD	4.0	3.4	3.0	2.8	2.8	3.0	3.4	3.5
GASOLINE, DIESEL	37.8	52.1	72.0	87.0	112.4	152.2	186.0	162.1
OTHER(COPPER SMELTERS)	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	95.0	161.8	267.7	372.6	386.0	471.9	453.0	482.2

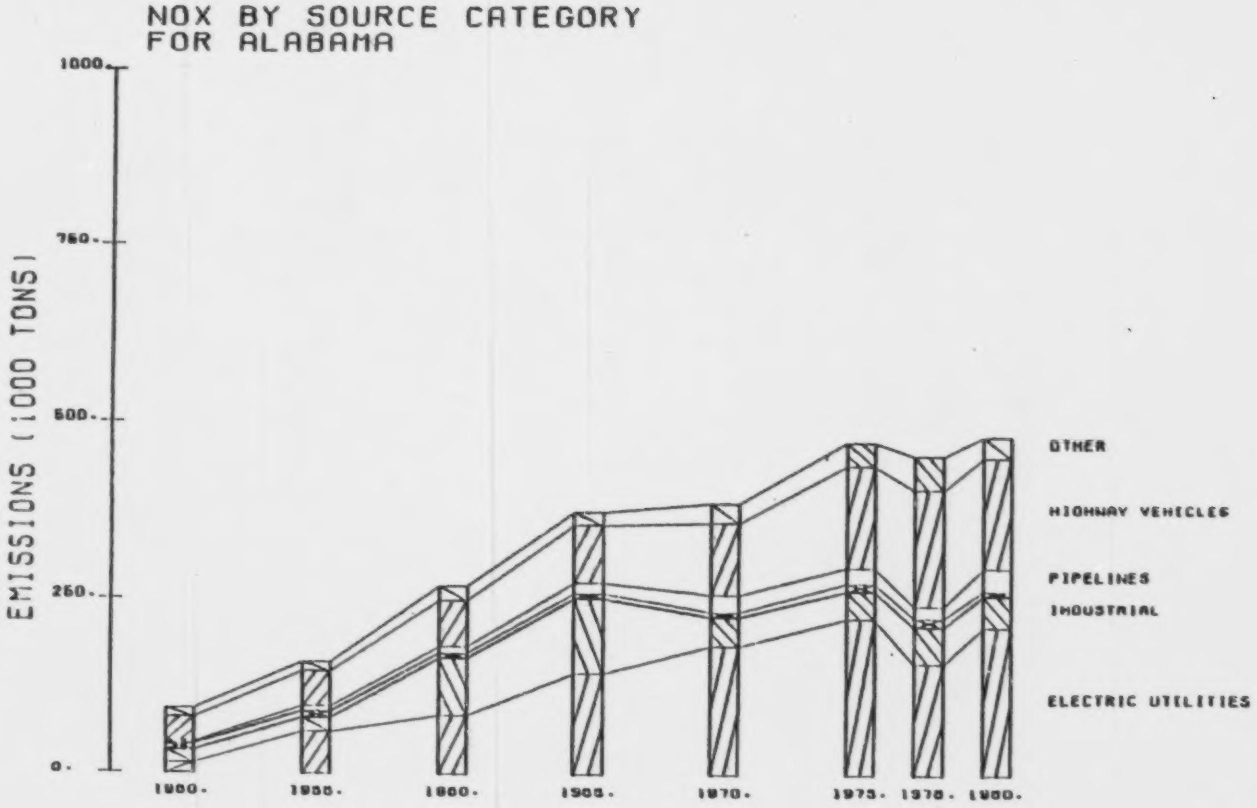


Figure 3. Historic trend in NO_x emissions by source category.

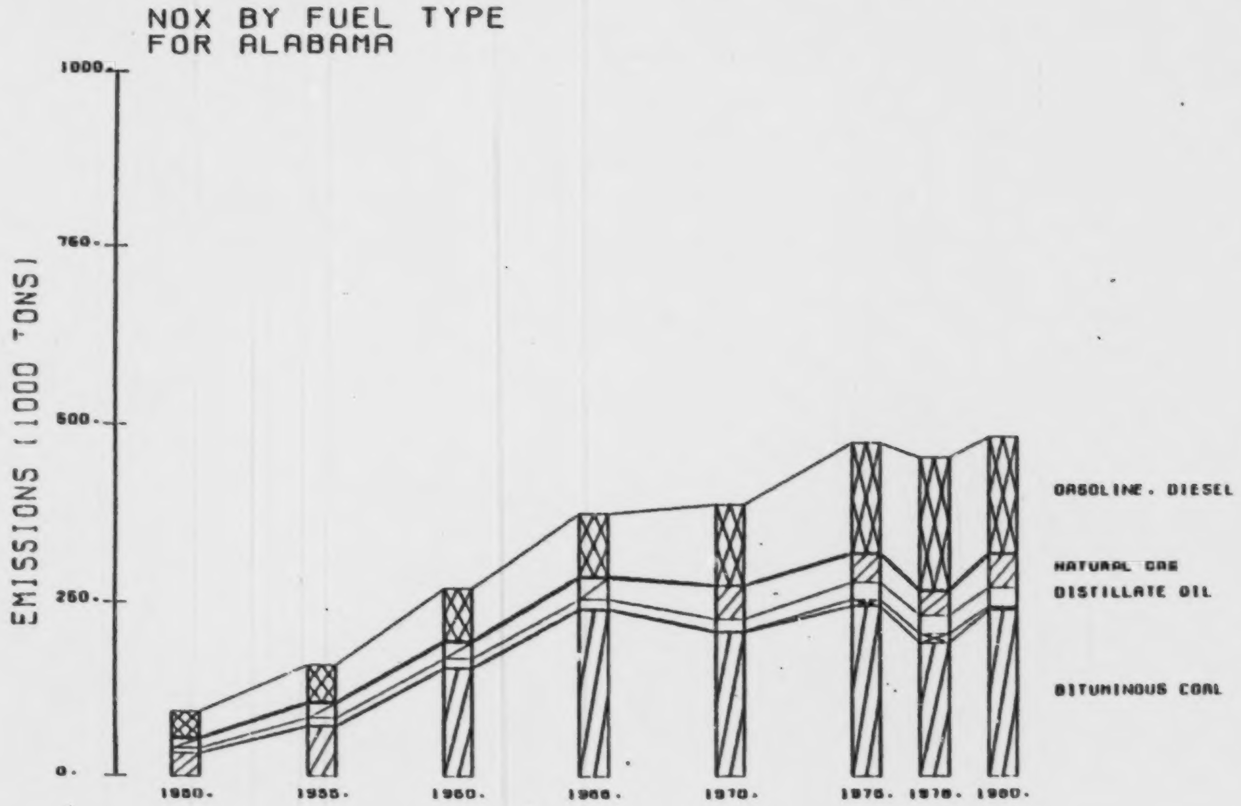


Figure 4. Historic trend in NO_x emissions by fuel type.

TABLE 1: FUEL CONSUMPTION 1900-1945 FOR THE STATE OF ARIZONA

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL(1000 TONS)										
ELECTRIC UTILITIES	1.	1.	2.	2.	2.	1.	0.	0.	0.	1.
INDUSTRIAL BOILERS	9.	16.	24.	34.	92.	191.	187.	143.	152.	162.
COMMERCIAL-RESIDENTIAL	19.	34.	53.	82.	91.	104.	106.	78.	74.	92.
ANTHRACITE COAL (1000 TONS)										
ALL USES	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RESIDUAL OIL (1000 BBL)										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	535.	425.	376.	466.	147.
INDUSTRIAL	NA	NA	NA	NA	NA	1451.	1387.	1373.	759.	904.
COMMERCIAL	NA	NA	NA	NA	NA	7.	11.	18.	38.	NA
DISTILLATE OIL (1000 BBL)										
ELECTRIC UTILITIES	NA	NA	NA	NA	NA	142.	113.	100.	72.	37.
INDUSTRIAL	NA	NA	NA	NA	NA	33.	31.	31.	31.	72.
COMMERCIAL -RESIDENTIAL	NA	NA	NA	NA	NA	52.	88.	142.	131.	261.
NATURAL GAS (10E6 CU. FT.)										
ELECTRIC UTILITIES	NA	NA	NA	NA	0.	0.	0.	1993.	2915.	2091.
INDUSTRIAL	NA	NA	0.	0.	0.	0.	0.	8485.	13083.	17352.
PIPELINES	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
COMMERCIAL-RESIDENTIAL	NA	NA	0.	0.	0.	0.	0.	1075.	2004.	5136.
WOOD (1000 TONS)										
ALL USES	513.	488.	467.	447.	426.	406.	385.	370.	359.	334.
HIGHWAY VEHICLES										
GASOLINE(1000 GAL)	NA	NA	NA	NA	NA	28864.	67616.	68714.	99998.	108820.
DIESEL (1000 GAL.)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MISCELLANEOUS										
RAILROADS-COAL(1000 TONS)	211.	378.	566.	736.	842.	678.	565.	428.	449.	612.
RAILROADS-OIL(1000 BBL)	NA	NA	NA	NA	NA	2372.	2230.	1828.	1982.	1749.
COKE PL (1000 TONS COAL)	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
VES FUEL OIL (1000 BBL)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
CEMENT PL (1000 TONS)	0.	NA	NA	0.	0.	0.	0.	0.	0.	0.

Omitted ARIZONA - WYOMING

(P. 3-17 to 3-688)

SUMMARY FOR THE UNITED STATES
EXCLUDING ALASKA AND HAWAII

TABLE 1. SUMMARY OF TOTAL SO_2 EMISSIONS BY STATE

STATES	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
ALABAMA	71.	105.	137.	160.	105.	202.	104.	144.	170.	230.
ARIZONA	4.	7.	11.	15.	10.	32.	29.	24.	21.	24.
ARKANSAS	63.	94.	122.	146.	156.	139.	110.	86.	86.	106.
CALIFORNIA	56.	75.	85.	92.	95.	339.	356.	326.	353.	690.
COLORADO	34.	48.	59.	70.	71.	69.	61.	45.	47.	50.
CONNECTICUT	93.	128.	152.	171.	179.	183.	140.	117.	142.	176.
DELAWARE	2.	3.	3.	3.	3.	9.	9.	8.	9.	10.
DISTRICT OF COLUMBIA	17.	22.	23.	23.	23.	20.	26.	21.	25.	20.
FLORIDA	12.	24.	30.	52.	62.	102.	98.	80.	110.	184.
GEORGIA	63.	90.	114.	135.	150.	160.	144.	112.	120.	163.
IDAHO	13.	19.	25.	31.	33.	30.	27.	22.	24.	34.
ILLINOIS	1380.	1910.	2362.	2779.	2850.	2818.	2502.	2099.	2460.	3366.
INDIANA	423.	644.	864.	1083.	1247.	1344.	1229.	970.	1133.	1505.
IOWA	439.	503.	607.	702.	762.	695.	617.	469.	510.	647.
KANSAS	220.	300.	351.	369.	375.	366.	317.	229.	235.	203.
KENTUCKY	106.	250.	299.	339.	360.	397.	302.	312.	372.	516.
LOUISIANA	90.	140.	177.	207.	209.	212.	105.	130.	137.	176.
MAINE	46.	68.	84.	99.	105.	99.	73.	58.	60.	85.
MARYLAND	96.	129.	151.	167.	170.	192.	175.	153.	193.	277.
MASSACHUSETTS	205.	270.	310.	336.	340.	380.	319.	253.	201.	335.
MICHIGAN	212.	338.	460.	614.	716.	831.	790.	654.	797.	1056.
MINNESOTA	186.	269.	341.	407.	443.	432.	373.	282.	293.	360.
MISSISSIPPI	51.	76.	100.	120.	133.	119.	110.	95.	116.	177.
MISSOURI	414.	572.	698.	823.	828.	824.	737.	564.	613.	767.
MONTANA	32.	46.	59.	70.	74.	72.	64.	48.	48.	70.
NEBRASKA	183.	241.	277.	290.	296.	269.	223.	159.	160.	192.
NEVADA	6.	10.	14.	18.	20.	24.	21.	16.	15.	23.
NEW HAMPSHIRE	41.	56.	65.	71.	73.	65.	44.	34.	43.	51.
NEW JERSEY	243.	363.	462.	550.	610.	710.	669.	533.	632.	852.
NEW MEXICO	8.	14.	21.	27.	31.	30.	26.	19.	19.	25.
NEW YORK	636.	804.	1040.	1177.	1262.	1203.	1137.	887.	1097.	1315.
NORTH CAROLINA	30.	52.	77.	106.	137.	163.	172.	152.	195.	286.
NORTH DAKOTA	11.	18.	27.	36.	40.	36.	28.	21.	25.	34.
OHIO	939.	1303.	1685.	1072.	1993.	2049.	1079.	1543.	1840.	2495.
OKLAHOMA	52.	100.	179.	258.	297.	296.	258.	189.	189.	230.
OREGON	8.	13.	19.	25.	27.	58.	53.	47.	46.	77.
PENNSYLVANIA	681.	1033.	1354.	1673.	1874.	2062.	1679.	1244.	1418.	1696.
RHODE ISLAND	46.	61.	69.	73.	74.	101.	76.	65.	75.	72.
SOUTH CAROLINA	20.	34.	50.	68.	84.	93.	95.	84.	106.	149.
SOUTH DAKOTA	12.	18.	22.	27.	28.	26.	22.	17.	22.	31.
TENNESSEE	124.	171.	208.	242.	263.	281.	298.	275.	350.	543.
TEXAS	208.	275.	315.	331.	337.	463.	435.	342.	360.	595.
UTAH	16.	24.	34.	44.	49.	51.	40.	30.	40.	53.
VERMONT	32.	44.	51.	56.	58.	49.	30.	23.	29.	34.
VIRGINIA	73.	115.	153.	193.	210.	224.	227.	209.	269.	409.
WASHINGTON	20.	43.	59.	75.	83.	107.	97.	81.	75.	120.
WEST VIRGINIA	66.	109.	155.	204.	240.	261.	249.	205.	250.	353.
WISCONSIN	233.	334.	421.	505.	575.	634.	505.	474.	546.	711.
WYOMING	17.	21.	22.	22.	21.	26.	24.	19.	21.	41.
TOTAL	8140.2	11563.0	14423.0	17049.2	18284.0	19442.1	17525.5	14001.0	16219.7	21745.4

Total not ude mts; due iss incomplete data for 1940 to 1945. Refer to the individual

TABLE 1. (Continued)

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	195.	326.	600.	897.	869.	1055.	716.	720.
ARIZONA	1052.	1170.	1403.	1829.	2211.	1390.	864.	745.
ARKANSAS	52.	25.	13.	13.	22.	57.	113.	79.
CALIFORNIA	304.	391.	305.	293.	405.	314.	343.	404.
COLORADO	37.	34.	70.	95.	69.	95.	128.	130.
CONNECTICUT	151.	149.	244.	300.	201.	94.	108.	87.
DELAWARE	25.	38.	86.	104.	73.	81.	57.	96.
DISTRICT OF COLUMBIA	46.	39.	45.	50.	124.	33.	17.	7.
FLORIDA	144.	226.	227.	350.	500.	655.	651.	832.
GEORGIA	130.	162.	176.	295.	301.	637.	676.	792.
IDAHO	30.	30.	21.	24.	12.	10.	20.	16.
ILLINOIS	2481.	2347.	2220.	2567.	2520.	2135.	1612.	1477.
INDIANA	1142.	1157.	1772.	2115.	1985.	2026.	1753.	2040.
IOWA	501.	306.	359.	408.	368.	303.	386.	320.
KANSAS	168.	114.	91.	75.	113.	172.	215.	267.
KENTUCKY	361.	506.	601.	894.	1325.	1355.	1339.	1150.
LOUISIANA	74.	51.	33.	29.	41.	102.	194.	200.
MAINE	40.	32.	42.	54.	72.	62.	59.	50.
MARYLAND	206.	193.	352.	532.	440.	281.	303.	337.
MASSACHUSETTS	240.	237.	353.	452.	552.	267.	392.	330.
MICHIGAN	923.	999.	1203.	1678.	1595.	1465.	1070.	884.
MINNESOTA	109.	145.	274.	307.	303.	204.	206.	171.
MISSISSIPPI	62.	25.	12.	8.	51.	139.	248.	193.
MISSOURI	421.	436.	493.	595.	796.	1222.	1199.	1220.
MONTANA	144.	197.	230.	270.	264.	190.	214.	140.
NEBRASKA	87.	50.	50.	72.	74.	40.	75.	65.
NEVADA	155.	222.	213.	204.	304.	250.	44.	53.
NEW HAMPSHIRE	25.	23.	29.	40.	94.	80.	67.	94.
NEW JERSEY	522.	420.	453.	607.	532.	275.	271.	307.
NEW MEXICO	130.	133.	100.	210.	412.	379.	388.	459.
NEW YORK	1126.	887.	1339.	1504.	1370.	1039.	983.	900.
NORTH CAROLINA	261.	266.	253.	331.	539.	532.	555.	551.
NORTH DAKOTA	54.	45.	42.	36.	48.	62.	87.	111.
OHIO	2120.	1996.	2929.	3173.	3182.	3180.	2792.	2764.
OKLAHOMA	102.	70.	30.	35.	19.	24.	54.	103.
OREGON	61.	57.	45.	40.	49.	40.	42.	53.
PENNSYLVANIA	1545.	1493.	2216.	2514.	2319.	1979.	1713.	1933.
RHODE ISLAND	68.	77.	80.	43.	59.	24.	21.	13.
SOUTH CAROLINA	123.	110.	116.	120.	197.	199.	207.	295.
SOUTH DAKOTA	23.	20.	17.	20.	62.	40.	56.	47.
TENNESSEE	340.	477.	798.	768.	1024.	1453.	1142.	1149.
TEXAS	222.	275.	153.	144.	113.	342.	516.	630.
UTAH	550.	354.	274.	308.	237.	222.	339.	293.
VERMONT	10.	7.	7.	10.	12.	6.	9.	6.
VIRGINIA	352.	305.	343.	409.	463.	345.	335.	285.
WASHINGTON	173.	178.	153.	134.	148.	172.	233.	202.
WEST VIRGINIA	333.	368.	597.	802.	955.	1440.	1219.	1168.
WISCONSIN	416.	406.	588.	600.	879.	665.	969.	640.
WYOMING	26.	23.	34.	64.	56.	102.	161.	216.
TOTAL	18053.1	17695.2	22105.7	26603.2	20688.6	27312.5	25245.4	25171.3

TABLE 2. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR THE U.S.

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
ELECTRIC UTILITIES	412.1	682.5	933.2	1245.2	1852.4	2112.5	2081.0	1525.1	2302.3	3442.0
INDUSTRIAL	3229.1	4491.7	5644.0	6771.0	7056.4	7912.8	6722.3	5464.0	6117.0	6963.4
COMMERCIAL-RESIDENTIAL	1137.8	1616.2	2094.4	2739.6	2064.4	3315.1	3629.9	3033.2	3230.7	5024.7
PIPELINES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
HIGHWAY VEHICLES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
OTHER	3369.2	4773.5	5750.7	6293.4	6810.0	6101.7	5092.3	3978.6	4401.7	6315.3
TOTAL	8148.2	11563.0	14423.0	17049.2	18284.0	19442.1	17525.5	14001.0	16219.7	21745.4

*- MAY NOT INCLUDE ALL EMISSIONS BECAUSE DATUM WAS NOT AVAILABLE

TABLE 2. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR THE U.S.

SOURCE CATEGORY	1950	1955	1960	1965	1970	1975	1978	1980
ELECTRIC UTILITIES	4510.2	6564.1	9243.1	12615.2	17662.4	19464.3	17404.0	17971.1
INDUSTRIAL	7305.9	7734.6	10101.5	11610.6	8413.8	5704.9	5594.7	5271.9
COMMERCIAL - RESIDENTIAL	2067.6	1977.5	2001.7	1810.4	1913.2	1342.2	1240.7	946.1
PIPELINES	.0	.1	.3	.4	.6	.6	.6	.5
HIGHWAY VEHICLES	101.1	128.1	144.2	190.6	297.7	346.0	455.6	477.0
OTHER	3260.2	1290.9	615.0	440.1	400.9	354.5	460.0	504.7
TOTAL	18053.1	17695.2	22105.7	26603.2	28688.6	27312.5	25245.4	25171.3

TABLE 3. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY FUEL TYPE FOR THE U.S.

FUEL TYPE	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL	7349.6	10488.1	13264.3	15835.7	17060.4	17159.1	15624.2	12318.3	14244.0	18774.0
ANTHRACITE COAL	783.5	1061.4	1144.8	1200.2	1210.8	904.2	472.4	356.9	593.9	603.7
RESIDUAL OIL	.0	.0	.0	.0	.0	1232.1	1280.5	1182.7	1222.9	2082.5
DISTILLATE OIL	.0	.0	.0	.0	.0	134.3	136.6	132.5	147.4	274.0
NATURAL GAS	.0	.0	.2	.2	.2	.4	.6	.5	.8	1.3
WOOD	15.1	14.4	13.8	13.2	12.6	12.0	11.4	10.9	10.6	9.8
GASOLINE, DIESEL	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	8148.2	11563.8	14423.0	17049.2	18284.0	19442.1	17525.5	14001.8	16219.7	21745.4

*- MAY NOT INCLUDE ALL EMISSIONS BECAUSE DATUM WAS NOT AVAILABLE

TABLE 3. SUMMARY OF SO2 EMISSIONS (1000 TONS) BY FUEL TYPE FOR THE U.S.

FUEL TYPE	1950	1955	1960	1965	1970	1975	1978	1980
BITUMINOUS COAL	13258.4	12885.4	16779.1	20553.9	20476.1	20512.4	18639.3	19578.0
ANTHRACITE COAL	572.7	359.9	246.7	178.7	129.0	80.2	85.4	61.3
RESIDUAL OIL	1759.1	1847.5	2059.4	2243.4	3672.1	3322.2	3782.5	3230.5
DISTILLATE OIL	315.2	338.9	609.5	570.3	575.1	576.9	655.9	468.0
NATURAL GAS	2.2	3.0	3.9	4.9	6.3	5.9	5.8	6.3
WOOD	14.2	11.8	10.3	9.1	9.1	9.5	13.3	15.5
GASOLINE, DIESEL	110.3	141.6	168.6	230.8	329.5	397.3	500.0	506.0
OTHER(COPPER SMELTERS)	2021.0	2107.2	2308.3	2892.1	3491.4	2408.2	1563.2	1305.7
TOTAL	18053.1	17695.2	22185.7	26683.2	28688.6	27312.5	25245.4	25171.3

TABLE 4. SUMMARY OF TOTAL NO$_x$ EMISSIONS BY STATE

STATES	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
ALABAMA	28.	27.	34.	41.	44.	62.	65.	57.	74.	95.
ARIZONA	1.	2.	3.	4.	5.	29.	32.	29.	34.	35.
ARKANSAS	9.	11.	13.	16.	17.	43.	46.	39.	48.	59.
CALIFORNIA	20.	24.	28.	29.	33.	340.	395.	373.	438.	624.
COLORADO	25.	35.	43.	51.	51.	59.	57.	46.	54.	65.
CONNECTICUT	27.	37.	43.	48.	50.	65.	65.	63.	82.	81.
DELAWARE	2.	2.	2.	2.	2.	5.	7.	8.	11.	10.
DISTRICT OF COLUMBIA	6.	7.	8.	8.	8.	14.	10.	21.	29.	24.
FLORIDA	4.	6.	8.	10.	11.	49.	51.	52.	72.	85.
GEORGIA	19.	24.	29.	33.	36.	56.	61.	68.	77.	87.
IDAHO	5.	7.	8.	10.	11.	16.	18.	17.	22.	26.
ILLINOIS	192.	264.	323.	302.	309.	467.	467.	415.	822.	600.
INDIANA	61.	92.	122.	154.	177.	237.	239.	210.	259.	309.
IOWA	51.	68.	80.	92.	89.	110.	115.	104.	124.	137.
KANSAS	27.	35.	47.	48.	48.	120.	127.	126.	115.	153.
KENTUCKY	28.	37.	45.	51.	56.	75.	81.	74.	97.	119.
LOUISIANA	12.	16.	20.	25.	26.	90.	97.	81.	91.	119.
MAINE	20.	27.	32.	37.	38.	41.	36.	33.	41.	41.
MARYLAND	28.	37.	42.	47.	47.	63.	66.	65.	87.	105.
MASSACHUSETTS	43.	82.	94.	103.	104.	150.	156.	144.	169.	159.
MICHIGAN	40.	72.	98.	128.	149.	232.	260.	240.	311.	346.
MINNESOTA	30.	42.	50.	58.	63.	89.	89.	83.	102.	104.
MISSISSIPPI	13.	17.	21.	24.	25.	33.	37.	36.	51.	66.
MISSOURI	56.	75.	91.	106.	106.	148.	162.	140.	178.	180.
MONTANA	12.	16.	21.	25.	26.	42.	42.	37.	42.	77.
NEBRASKA	25.	33.	30.	42.	41.	55.	57.	48.	51.	54.
NEVADA	2.	3.	4.	5.	6.	42.	40.	34.	31.	57.
NEW HAMPSHIRE	17.	23.	26.	28.	28.	29.	22.	20.	26.	25.
NEW JERSEY	77.	110.	132.	151.	163.	215.	239.	211.	200.	294.
NEW MEXICO	3.	5.	7.	9.	10.	14.	16.	16.	20.	32.
NEW YORK	208.	285.	330.	367.	390.	485.	519.	453.	500.	557.
NORTH CAROLINA	13.	18.	23.	29.	37.	68.	82.	84.	115.	140.
NORTH DAKOTA	5.	9.	12.	17.	18.	22.	20.	19.	21.	20.
OHIO	154.	212.	267.	316.	334.	420.	442.	380.	493.	579.
OKLAHOMA	6.	11.	18.	20.	36.	124.	142.	114.	120.	120.
OREGON	8.	10.	11.	13.	13.	80.	83.	74.	81.	117.
PENNSYLVANIA	239.	347.	441.	526.	579.	656.	573.	483.	593.	623.
RHODE ISLAND	19.	25.	28.	30.	30.	36.	32.	30.	37.	34.
SOUTH CAROLINA	8.	11.	14.	18.	21.	35.	40.	40.	57.	68.
SOUTH DAKOTA	7.	10.	12.	14.	15.	22.	23.	23.	27.	30.
TENNESSEE	25.	32.	37.	43.	47.	66.	81.	91.	113.	156.
TEXAS	18.	23.	26.	28.	33.	283.	340.	317.	381.	590.
UTAH	6.	9.	12.	15.	17.	24.	25.	22.	27.	35.
VERMONT	15.	20.	22.	24.	25.	24.	17.	15.	20.	19.
VIRGINIA	23.	33.	43.	53.	59.	77.	90.	93.	128.	164.
WASHINGTON	13.	18.	22.	27.	29.	72.	79.	73.	76.	95.
WEST VIRGINIA	18.	20.	44.	57.	67.	83.	87.	77.	103.	124.
WISCONSIN	43.	59.	72.	86.	97.	138.	148.	130.	159.	132.
WYOMING	7.	8.	9.	9.	10.	26.	25.	20.	23.	35.
TOTAL	1733.8	2399.6	2955.1	3472.6	3720.1	5747.1	6016.0	5415.7	4695.3	7036.7

TABLE 4. (Continued)

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	95.	162.	260.	373.	386.	472.	453.	482.
ARIZONA	41.	48.	84.	101.	142.	193.	260.	316.
ARKANSAS	76.	83.	94.	121.	160.	163.	210.	212.
CALIFORNIA	503.	546.	648.	859.	1162.	1159.	1230.	1221.
COLORADO	56.	73.	102.	120.	154.	224.	265.	304.
CONNECTICUT	74.	90.	117.	142.	171.	152.	153.	139.
DELAWARE	16.	22.	30.	46.	49.	45.	48.	60.
DISTRICT OF COLUMBIA	27.	25.	25.	28.	46.	29.	26.	19.
FLORIDA	96.	151.	207.	273.	452.	572.	610.	663.
GEORGIA	100.	140.	171.	237.	354.	474.	511.	535.
IDAHO	20.	31.	33.	43.	50.	64.	73.	107.
ILLINOIS	550.	614.	743.	873.	976.	998.	976.	903.
INDIANA	277.	340.	490.	603.	627.	692.	699.	839.
IOWA	146.	159.	170.	196.	265.	273.	280.	304.
KANSAS	137.	172.	180.	208.	304.	330.	402.	429.
KENTUCKY	117.	177.	234.	323.	435.	519.	537.	545.
LOUISIANA	125.	174.	359.	519.	720.	785.	1203.	754.
MAINE	30.	34.	40.	46.	58.	60.	66.	58.
MARYLAND	90.	108.	173.	254.	254.	245.	250.	260.
MASSACHUSETTS	130.	152.	201.	248.	204.	271.	207.	250.
MICHIGAN	313.	362.	402.	640.	752.	751.	759.	714.
MINNESOTA	97.	117.	173.	197.	256.	209.	301.	293.
MISSISSIPPI	67.	80.	115.	147.	216.	206.	236.	247.
MISSOURI	163.	206.	313.	294.	308.	469.	522.	510.
MONTANA	64.	51.	57.	62.	72.	86.	110.	121.
NEBRASKA	56.	69.	81.	91.	133.	147.	176.	161.
NEVADA	36.	27.	25.	36.	45.	93.	101.	100.
NEW HAMPSHIRE	17.	19.	22.	29.	48.	49.	52.	53.
NEW JERSEY	267.	249.	275.	347.	435.	393.	380.	382.
NEW MEXICO	42.	60.	78.	125.	242.	264.	288.	319.
NEW YORK	537.	544.	679.	790.	857.	707.	751.	603.
NORTH CAROLINA	161.	203.	229.	312.	472.	497.	530.	547.
NORTH DAKOTA	33.	33.	39.	43.	78.	93.	124.	137.
OHIO	557.	626.	838.	948.	1059.	1135.	1103.	1154.
OKLAHOMA	115.	115.	123.	159.	337.	365.	425.	464.
OREGON	96.	82.	85.	104.	128.	145.	176.	180.
PENNSYLVANIA	619.	667.	926.	1047.	988.	1050.	1078.	1120.
RHODE ISLAND	26.	36.	37.	28.	43.	40.	30.	34.
SOUTH CAROLINA	70.	89.	111.	135.	201.	214.	257.	261.
SOUTH DAKOTA	26.	29.	32.	30.	54.	64.	81.	75.
TENNESSEE	129.	199.	280.	327.	409.	566.	560.	554.
TEXAS	531.	577.	1208.	1499.	1940.	2203.	2500.	2365.
UTAH	62.	63.	80.	81.	77.	114.	136.	166.
VERMONT	11.	13.	14.	16.	20.	22.	25.	24.
VIRGINIA	176.	190.	249.	324.	376.	353.	367.	378.
WASHINGTON	94.	95.	108.	125.	164.	230.	270.	272.
WEST VIRGINIA	131.	164.	196.	270.	313.	440.	438.	493.
WISCONSIN	143.	163.	232.	207.	379.	371.	398.	423.
WYOMING	37.	52.	52.	71.	140.	171.	254.	321.
TOTAL	7389.5	8490.2	11525.3	14199.2	17600.4	19252.0	21110.1	20904.6

TABLE 5. SUMMARY OF NOX EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR THE U.S.

SOURCE CATEGORY	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
ELECTRIC UTILITIES	99.3	164.4	224.7	299.9	303.7	503.3	524.4	389.1	611.9	906.0
INDUSTRIAL	690.7	965.1	1245.4	1503.1	1588.3	1826.4	1602.5	1312.7	1502.6	1782.0
COMMERCIAL-RESIDENTIAL	179.5	256.9	343.9	452.2	478.1	554.0	614.2	519.3	571.4	899.5
PIPELINES	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
HIGHWAY VEHICLES	.0	.0	.0	.0	.0	1071.1	1005.5	2010.7	2690.7	2339.9
OTHER	764.4	1013.3	1141.0	1217.4	1270.0	1791.5	1469.4	1183.8	1310.6	1959.3
TOTAL	1733.8	2399.6	2955.1	3472.6	3720.1	5747.1	6016.0	5415.7	6695.3	7886.7

TABLE 5. SUMMARY OF NOX EMISSIONS (1000 TONS) BY SOURCE CATEGORY FOR THE U.S.

SOURCE CATEGORY	1950	1955	1960	1965	1970	1975	1978	1980
ELECTRIC UTILITIES	1295.0	1934.9	2573.6	3465.0	5076.7	6174.3	6643.1	7083.9
INDUSTRIAL	1410.3	1569.5	2380.8	2717.7	1605.0	1315.7	1495.8	1408.4
COMMERCIAL - RESIDENTIAL	709.5	552.6	796.2	826.1	980.0	859.7	883.4	782.6
PIPELINES	150.7	307.3	1106.6	1550.9	2527.2	2347.3	2592.9	1956.0
HIGHWAY VEHICLES	2205.5	2094.8	3468.9	4411.9	6206.3	7352.7	8054.6	7580.6
OTHER	1538.4	1239.1	1199.2	1227.7	1205.2	1203.1	1440.2	1293.0
TOTAL	7309.5	8498.2	11525.3	14199.2	17600.4	19252.0	21110.1	20984.6

TABLE 6. SUMMARY OF NOX EMISSIONS (1000 TONS) BY FUEL TYPE FOR THE U.S.

FUEL TYPE	1900	1905	1910	1915	1920	1925	1930	1935	1940	1945
BITUMINOUS COAL	1205.9	1730.5	2213.2	2699.9	2930.0	3082.1	2815.3	2219.7	2620.8	3393.2
ANTHRACITE COAL	414.4	561.3	605.4	634.7	640.3	478.2	249.8	188.8	314.1	319.3
RESIDUAL OIL	.0	.0	.0	.0	.0	225.9	239.0	223.5	228.4	392.0
DISTILLATE OIL	.0	.0	.0	.0	.0	711.1	672.5	559.1	555.4	1032.5
NATURAL GAS	.0	.0	33.1	39.2	55.6	89.0	149.7	132.2	206.3	335.9
WOOD	113.5	107.9	103.3	98.8	94.2	89.7	85.2	81.7	79.5	73.8
GASOLINE, DIESEL	.0	.0	.0	.0	.0	1071.1	1805.5	2010.7	2690.7	2339.9
TOTAL	1733.8	2399.6	2955.1	3472.6	3720.1	5747.1	6016.0	5415.7	6695.3	7886.7

TABLE 6. SUMMARY OF NOX EMISSIONS (1000 TONS) BY FUEL TYPE FOR THE U.S.

FUEL TYPE	1950	1955	1960	1965	1970	1975	1978	1980
BITUMINOUS COAL	2507.9	2717.3	3849.6	4816.8	4699.5	5427.3	5879.3	7161.5
ANTHRACITE COAL	302.9	190.4	130.4	94.5	68.2	42.4	45.2	32.4
RESIDUAL OIL	401.1	419.6	495.1	528.1	846.3	943.9	1130.5	854.2
DISTILLATE OIL	938.2	870.3	968.6	968.4	1002.7	1036.6	1133.9	1053.1
NATURAL GAS	725.9	1134.0	2227.3	2905.3	4306.0	3981.9	4205.5	3812.4
WOOD	115.7	98.0	86.5	79.7	80.8	84.8	117.3	134.4
GASOLINE, DIESEL	2397.8	3060.6	3767.9	4806.6	6596.8	7735.9	8598.3	7936.5
OTHER(COPPER SMELTERS)	.0	.0	.0	.0	.0	.0	.0	.0
TOTAL	7389.5	8490.2	11525.3	14199.2	17680.4	19252.8	21110.1	20984.6

SECTION 4

DISCUSSION

The source categories studied account for about 90 to 95 percent of the total national emissions, at least in recent years. The categories do not include zinc and lead smelters, sour gas processing plants, petroleum refineries, coal refuse piles and other sources which may have emitted significant quantities of SO_2 and NO_x in certain states. These sources could not be included in this study because historic data on the various processes were not readily available. In the case of smelters and other large point sources, information on the efficiency of air pollution control devices and plant production rates are often not available on an historic basis.

QUALITY ASSURANCE

Estimates for years prior to 1950 may not necessarily be based on state level data. The further back in time, the less reliable the estimates become. Emissions for the early years (1900-1945) are provided only to show the general trend in emissions according to fuel type and source category.

As with any emission inventory, the "true" value of emissions is unknown. Only through extremely detailed and costly source emission measurements can an "accurate" value be obtained. On the state level, where there are thousands, if not millions of sources, such an approach would be impossible. Therefore, true error cannot be determined.

Errors in the emissions data of this study result mostly from sampling errors. Imprecision is caused by variation or scatter of the input data bases. For example, emission factors result in imprecision because they are averages based on a number of scattered observations. Sulfur content data also results in imprecision. In this study, the most precise data are the fuel consumption data which were obtained from various Government agencies utilizing extensive surveying and sampling techniques. The least precise are probably the emission factors.

The reliability of the SO_2 and NO_x emissions data can best be seen by comparing the data to other inventories. This is possible for 1980. Table 12 compares the total SO_2 and NO_x emissions with the quantities reported by Work Group 3B and the SO_2 emissions from electric utilities with the quantities reported by E.H. Pechan. [81,82]

The total national SO_2 and NO_x emissions reported by Work Group 3B have a probable error of 2.3 and 2.0 percent, respectively. On the state level, the probable error is higher. Nevertheless, the results of this study compare well with the results of these other studies of 1980 with a few exceptions.

On an historic basis, the results compare well with EPA estimates for 1940 to 1980.[83] The results of this study may be more reliable because a more refined methodology was used, but the EPA estimates include all other sources. The data are not compared in this report for the sake of brevity.

TABLE 12. COMPARISON OF ESTIMATES FOR 1980 (1,000 tons)

	Total SO_2		SO_2 Electric Utilities		TOTAL NO_x	
	Work Group 3B	This Study	E. Pechan	This Study	Work Group 3B	This Study
Alabama	759.	728.	543.	560.	450.	482.
Arizona	900.	745.	88.	85.	258.	316.
Arkansas	102.	79.	27.	38.	217.	212.
California	446.	404.	78.	84.	1,225.	1,221.
Colorado	132.	138.	77.	93.	276.	304.
Connecticut	72.	87.	32.	20.	134.	139.
Delaware	109.	96.	52.	54.	52.	60.
D.C.	15.	7.	5.	2.	22.	19.
Florida	1,095.	832.	726.	644.	648.	663.
Georgia	840.	792.	737.	706.	494.	535.
Idaho	47.	16.	0.	0.	81.	107.
Illinois	1,471.	1,477.	1,126.	1,191.	1,005.	903.
Indiana	2,008.	2,040.	1,540.	1,644.	773.	839.
Iowa	329.	328.	231.	312.	321.	304.
Kansas	223.	267.	150.	222.	437.	429.
Kentucky	1,121.	1,158.	1,008.	1,053.	531.	545.
Louisiana	304.	288.	25.	40.	928.	754.
Maine	95.	50.	16.	14.	59.	58.
Maryland	338.	337.	223.	245.	248.	268.
Massachusetts	344.	338.	275.	265.	254.	258.
Michigan	907.	884.	565.	604.	690.	714.
Minnesota	250.	171.	177.	123.	373.	293.
Mississippi	285.	193.	129.	137.	285.	247.
Missouri	1,301.	1,228.	1,141.	1,100.	568.	510.
Montana	164.	148.	23.	31.	126.	121.
Nebraska	75.	65.	49.	50.	195.	161.
Nevada	220.	53.	34.	45.	83.	108.
New Hampshire	93.	94.	80.	82.	56.	53.
New Jersey	279.	307.	110.	107.	406.	382.
New Mexico	269.	459.	85.	113.	289.	319.
New York	944.	900.	480.	462.	680.	683.
North Carolina	602.	551.	435.	430.	536.	547.
North Dakota	107.	111.	86.	93.	125.	137.
Ohio	2,647.	2,764.	2,172.	2,346.	1,145.	1,154.
Oklahoma	121.	103.	38.	59.	526.	464.
Oregon	60.	53.	3.	12.	192.	180.
Pennsylvania	2,022.	1,933.	1,466.	1,415.	1,038.	1,128.
Rhode Island	15.	13.	5.	4.	36.	34.
South Carolina	326.	295.	213.	203.	260.	261.
South Dakota	39.	47.	29.	38.	89.	75.
Tennessee	1,077.	1,149.	934.	1,003.	517.	554.
Texas	1,277.	630.	303.	298.	2,544.	2,365.
Utah	72.	293.	22.	28.	144.	166.
Vermont	7.	6.	1.	0.	25.	24.
Virginia	361.	288.	164.	158.	405.	378.
Washington	272.	202.	69.	83.	289.	272.
West Virginia	1,088.	1,168.	944.	1,060.	452.	493.
Wisconsin	637.	640.	486.	524.	420.	423.
Wyoming	184.	216.	118.	168.	255.	321.
Total	26,461.	25,171.	17,320.	17,971.	21,162.	20,985.

SECTION 5
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APPENDIX A
FUEL SULFUR CONTENT DATA

Note: All sulfur content data is expressed as percentage by weight.

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TABLE A-1. PERCENT SULFUR CONTENT OF BITUMINOUS COAL ELECTRICAL UTILITIES

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	2.130	2.130	2.200	2.200	2.467	2.357	1.836	1.590
ARIZONA	.050	.050	1.300	1.300	.420	.459	.406	.470
ARKANSAS	3.900	3.900	.000	.000	.000	.000	.380 *	.380
CALIFORNIA	.000	.000	.000	.000	.000	.000	.000	.000
COLORADO	.570	.570	.900	.900	.564	.413	.446	.440
CONNECTICUT	1.630	1.630	2.300	2.300	2.270	.000	2.300 *	.000
DELAWARE	1.660	1.660	2.100	2.100	1.249	.700	1.000 *	1.540
DISTRICT OF COLUMBIA	1.870	1.870	1.800	1.800	3.429	3.169	1.847	.000
FLORIDA	2.820	2.820	2.200	2.200	1.445	1.876	1.970	2.100
GEORGIA	2.820	2.820	2.200	2.200	1.922	1.886	1.724	1.850
IDAHO	.820	.820	.900	.900	.000	.000	.000	.000
ILLINOIS	3.250	3.250	3.100	3.100	3.219	2.579	1.990	1.840
INDIANA	3.040	3.040	3.400	3.400	3.452	2.854	2.540	2.620
IOWA	3.780	3.780	4.000	4.000	2.709	1.963	1.594	1.080
KANSAS	3.930	3.930	4.000	4.000	3.579	3.598	1.553	1.230
KENTUCKY	2.930	2.930	2.900	2.900	3.055	2.548	2.727	2.510
LOUISIANA	3.900	3.900	.000	.000	.000	.000	.440 *	.440
MAINE	1.190	1.190	2.100	2.100	.000	.000	.000	.000
MARYLAND	1.660	1.660	2.100	2.100	2.214	1.672	1.480	1.640
MASSACHUSETTS	1.460	1.460	1.500	1.500	2.646	.851	.000	1.160
MICHIGAN	2.500	2.500	2.400	2.400	2.578	2.424	1.844	1.300
MINNESOTA	2.370	2.370	2.800	2.800	2.836	1.459	.999	.940
MISSISSIPPI	2.130	2.130	2.200	2.200	3.796	1.656	2.231	1.640
MISSOURI	3.890	3.890	3.800	3.800	2.810	3.886	2.662	2.620
MONTANA	.820	.820	.900	.900	.703	.696	.610	.750
NEBRASKA	3.930	3.930	4.000	4.000	3.194	.896	.782	.540
NEVADA	.050	.050	1.300	1.300	.650	.410	.552	.540
NEW HAMPSHIRE	1.190	1.190	2.100	2.100	2.420	2.340	2.160	2.540
NEW JERSEY	2.000	2.000	2.400	2.400	1.971	1.893	1.660	1.660
NEW MEXICO	.050	.050	1.300	1.300	.780	.572	.668	.720
NEW YORK	1.470	1.470	2.200	2.200	1.065	2.081	1.713	1.840
NORTH CAROLINA	1.450	1.450	1.200	1.200	1.124	1.131	1.075	.960
NORTH DAKOTA	2.380	2.380	1.100	1.100	.758	.617	.612	.650
OHIO	2.740	2.740	3.500	3.500	3.094	2.928	2.461	2.490
OKLAHOMA	3.900	3.900	.000	1.500 *	1.514	.000	.350	.380
OREGON	.820	.820	.000	.000	.000	.090	.560 *	.560
PENNSYLVANIA	1.750	1.750	2.200	2.200	2.579	2.092	2.112	2.110
RHODE ISLAND	1.190	1.190	2.100	2.100	.000	.000	2.000 *	.000
SOUTH CAROLINA	1.470	1.470	1.300	1.300	1.216	1.307	1.336	1.410
SOUTH DAKOTA	2.380	2.380	1.100	1.100	2.230	.770	.760	.700
TENNESSEE	2.000	2.000	2.700	2.700	2.862	2.806	2.482	2.260
TEXAS	3.900	3.900	.000	.000	.000	.553	.597	.600
UTAH	.880	.880	1.000	1.000	.550	.500	.530	.500
VERMONT	1.190	1.190	2.100	2.100	3.170	2.500 *	.000	.000
VIRGINIA	1.380	1.380	1.300	1.300	1.102	.833	.965	.880
WASHINGTON	.820	.820	.000	.000	.000	.510	.970	.810
WEST VIRGINIA	1.700	1.700	2.800	2.800	2.671	2.531	2.168	1.790
WISCONSIN	2.860	2.860	2.700	2.700	2.816	2.443	3.585	1.870
WYOMING	.810	.810	1.200	1.200	.550	.537	.504	.560

TABLE A-2. PERCENT SULFUR CONTENT OF BITUMINOUS COAL INDUSTRIAL BOILERS

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	1.610	1.610	1.650	1.650	1.200	1.059	1.049	1.049
ARIZONA	.800	.800	1.200	1.200	.500	.500	.512	.512
ARKANSAS	3.250	3.250	2.700	2.700	3.500	1.773	2.112	2.112
CALIFORNIA	.900	.900	.900 *	.900 *	.605 *	.606	.576	.576
COLORADO	.500	.500	1.000	1.000	.606	.742	.809	.809
CONNECTICUT	1.010	1.010	1.700	1.700	2.040	2.000	.800	.800
DELAWARE	1.630	1.630	1.600	1.600	1.930	.900	2.116	2.116
DISTRICT OF COLUMBIA	1.330	1.330	1.450	1.450	1.207	1.440	2.297	2.297
FLORIDA	1.520	1.520	1.650	1.650	1.200	1.200 *	1.130	1.130
GEORGIA	1.520	1.520	1.650	1.650	1.200	1.200	1.177	1.177
IDAHO	.870	.870	1.000	1.000	.661	.660	.693	.693
ILLINOIS	3.240	3.240	2.100	2.100	2.690	2.445	2.207	2.207
INDIANA	3.000	3.000	2.250	2.250	2.393	3.247	2.560	2.560
IOWA	3.500	3.500	2.550	2.550	2.713	2.553	1.934	1.934
KANSAS	2.920	2.920	2.550	2.550	3.500	1.700	2.101	2.101
KENTUCKY	2.670	2.670	2.000	2.000	3.171	1.742	1.644	1.644
LOUISIANA	3.250	3.250	2.700	2.700	3.800	.000	2.331	2.331
MAINE	1.350	1.350	1.600	1.600	1.670	2.344	1.100	1.100
MARYLAND	1.630	1.630	1.600	1.600	1.930	1.901	2.345	2.345
MASSACHUSETTS	1.550	1.550	1.300	1.300	1.503	2.045	1.793	1.793
MICHIGAN	2.190	2.190	1.750	1.750	1.701	1.557	1.027	1.027
MINNESOTA	2.210	2.210	1.950	1.950	1.942	2.121	1.069	1.069
MISSISSIPPI	1.610	1.610	1.650	1.650	1.200	1.055	2.507	2.507
MISSOURI	3.390	3.390	2.450	2.450	2.795	2.605	2.467	2.467
MONTANA	.870	.870	1.000	1.000	.661	.685	.690	.690
NEBRASKA	2.920	2.920	2.550	2.550	3.500	.800	.700	.700
NEVADA	.800	.800	1.200	1.200	.500	.590	.600	.600
NEW HAMPSHIRE	1.350	1.350	1.600	1.600	1.670	2.000	2.100	2.100
NEW JERSEY	1.500	1.500	1.750	1.750	1.607	2.642	1.505	1.505
NEW MEXICO	.850	.850	1.200	1.200	.500	.800	.575	.575
NEW YORK	1.620	1.620	1.650	1.650	1.081	2.059	2.103	2.103
NORTH CAROLINA	1.420	1.420	1.150	1.150	1.200	.901	1.103	1.103
NORTH DAKOTA	.400	.400	1.100	1.100	.611	.600	.700	.700
OHIO	2.520	2.520	2.300	2.300	2.453	2.109	2.511	2.511
OKLAHOMA	3.250	3.250	2.700	2.700	3.500	1.411	2.107	2.107
OREGON	.810	.810	.000	.000	.550	.605	.773	.773
PENNSYLVANIA	1.760	1.760	1.650	1.650	2.060	1.000	2.112	2.112
RHODE ISLAND	1.350	1.350	1.600	1.606	1.670	2.000	1.000	1.000
SOUTH CAROLINA	1.450	1.450	1.200	1.200	1.200	.900	1.099	1.099
SOUTH DAKOTA	.400	.400	1.100	1.100	.611	.676	.702	.702
TENNESSEE	1.010	1.010	1.900	1.900	1.960	1.400	1.951	1.951
TEXAS	3.250	3.250	2.700	2.700	3.500	1.633	1.792	1.792
UTAH	.800	.800	1.050	1.050	.537	.602	.600	.600
VERMONT	1.350	1.350	1.600	1.600	1.670	2.000	2.100	2.100
VIRGINIA	1.330	1.330	1.200	1.200	1.200	.801	1.140	1.140
WASHINGTON	.810	.810	.000	.000	.550	.611	.670	.670
WEST VIRGINIA	1.550	1.550	1.950	1.950	1.483	1.620	1.737	1.737
WISCONSIN	2.010	2.010	1.900	1.900	2.331	1.051	2.065	2.065
WYOMING	.820	.820	1.150	1.150	.700	.700	.697	.697

TABLE A-3. PERCENT SULFUR CONTENT OF BITUMINOUS COAL COMMERCIAL-RESIDENTIAL

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	1.640	1.640	1.650	1.650	1.200	1.900	1.300	1.300
ARIZONA	.000	.000	1.200	1.200	.500	.000	.000	.000
ARKANSAS	2.710	2.710	2.700	2.700	.000	.000	2.400	2.400
CALIFORNIA	.600 *	.600 *	.600 *	.600 *	.600	.600	.600	.600
COLORADO	.600	.600	1.000	1.000	.600	.700	.700	.700
CONNECTICUT	1.630	1.630	1.700	1.700	.830	.802	.802	1.700 *
DELAWARE	1.420	1.420	1.600	1.600	1.649	.000	.000	1.649 *
DISTRICT OF COLUMBIA	1.050	1.050	1.450	1.450	1.200	.600	.000	.600 *
FLORIDA	1.470	1.470	1.450	1.650	1.200	.000	.300	1.200 *
GEORGIA	1.470	1.470	1.650	1.650	1.200	.900	1.100	1.100
IDAHO	.860	.860	1.000	1.000	.534	.834 *	.656	.656
ILLINOIS	2.730	2.730	2.100	2.100	2.061	1.600	1.777	1.777
INDIANA	2.010	2.010	2.250	2.250	1.761	2.044	2.008	2.008
IOWA	2.030	2.030	2.550	2.550	1.395	.936	1.747	1.747
KANSAS	1.710	1.710	2.550	2.550	3.500	.000	2.100	2.100
KENTUCKY	2.140	2.140	2.600	2.000	1.976	1.241	1.381	1.381
LOUISIANA	2.710	2.710	2.700	2.700	2.700 *	.000	.000	2.700 *
MAINE	1.260	1.260	1.600	1.600	1.300	.600	.000	.600 *
MARYLAND	1.420	1.420	1.600	1.600	1.649	.642	1.733	1.733
MASSACHUSETTS	1.290	1.290	1.300	1.300	1.510	.600	.000	.600 *
MICHIGAN	1.390	1.390	1.750	1.750	1.763	.806	1.923	1.923
MINNESOTA	2.100	2.100	1.950	1.950	2.224	1.591	1.070	1.070
MISSISSIPPI	1.640	1.640	1.650	1.650	1.200	.000	.900	.900
MISSOURI	3.320	3.320	2.450	2.450	2.990	2.670	2.290	2.290
MONTANA	.860	.860	1.000	1.000	.534	.657	.700	.700
NEBRASKA	1.710	1.710	2.550	2.550	3.500	.700	.700	.700
NEVADA	.000	.000	1.200	1.200	.500	.600	.700	.700
NEW HAMPSHIRE	1.260	1.260	1.600	1.600	1.300	.000	.000	1.300 *
NEW JERSEY	1.460	1.460	1.750	1.750	2.566	3.200	.000	3.200 *
NEW MEXICO	.770	.770	1.200	1.200	.500	.000	.000	.500 *
NEW YORK	1.600	1.600	1.650	1.650	2.325	2.000	1.966	1.966
NORTH CAROLINA	1.420	1.420	1.150	1.150	1.200	.900	1.003	1.003
NORTH DAKOTA	.400	.400	1.100	1.100	.745	.620	.705	.705
OHIO	2.050	2.050	2.300	2.300	2.279	2.483	2.405	2.605
OKLAHOMA	2.710	2.710	2.700	2.700	.000	2.100 *	2.100	2.100
OREGON	.860	.860	.860 *	.860 *	.543	.422	.650	.650
PENNSYLVANIA	1.930	1.930	1.650	1.650	2.174	1.296	2.094	2.094
RHODE ISLAND	1.260	1.260	1.600	1.600	1.300	.000	.000	1.300 *
SOUTH CAROLINA	1.460	1.460	1.200	1.200	1.203	.900	1.100	1.100
SOUTH DAKOTA	.400	.400	1.100	1.100	.745	.807	1.100	1.100
TENNESSEE	3.010	3.010	1.900	1.900	1.356	.920	1.540	1.540
TEXAS	2.710	2.710	2.700	2.700	2.000 *	.000	.000	2.000 *
UTAH	1.000 *	1.000 *	1.050	1.050	.500	.602	.601	.601
VERMONT	1.260	1.260	1.600	1.600	1.300	1.300 *	.000	1.300 *
VIRGINIA	1.240	1.240	1.200	1.200	1.207	.877	1.059	1.059
WASHINGTON	.860	.860	.860 *	.860 *	.543	.676	.597	.597
WEST VIRGINIA	1.350	1.350	1.950	1.950	1.249	1.527	2.260	2.260
WISCONSIN	1.070	1.070	1.900	1.900	1.721	1.560	1.409	1.409
WYOMING	.730	.730	1.150	1.150	.700	.700	.696	.696

* Default value.

TABLE A-4. PERCENT SULFUR CONTENT OF ANTHRACITE COAL ALL USES

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	.800	.800	.800	.800	.800	.800	.800	.800
ARIZONA	.800	.800	.800	.800	.800	.800	.800	.800
ARKANSAS	.800	.800	.800	.800	.800	.800	.800	.800
CALIFORNIA	.800	.800	.800	.800	.800	.800	.800	.800
COLORADO	.800	.800	.800	.800	.800	.800	.800	.800
CONNECTICUT	.800	.800	.800	.800	.800	.800	.800	.800
DELAWARE	.800	.800	.800	.800	.800	.800	.800	.800
DISTRICT OF COLUMBIA	.800	.800	.800	.800	.800	.800	.800	.800
FLORIDA	.800	.800	.800	.800	.800	.800	.800	.800
GEORGIA	.800	.800	.800	.800	.800	.800	.800	.800
IDAHO	.800	.800	.800	.800	.800	.800	.800	.800
ILLINOIS	.800	.800	.800	.800	.800	.800	.800	.800
INDIANA	.800	.800	.800	.800	.800	.800	.800	.800
IOWA	.800	.800	.800	.800	.800	.800	.800	.800
KANSAS	.800	.800	.800	.800	.800	.800	.800	.800
KENTUCKY	.800	.800	.800	.800	.800	.800	.800	.800
LOUISIANA	.800	.800	.800	.800	.800	.800	.800	.800
MAINE	.800	.800	.800	.800	.800	.800	.800	.800
MARYLAND	.800	.800	.800	.800	.800	.800	.800	.800
MASSACHUSETTS	.800	.800	.800	.800	.800	.800	.800	.800
MICHIGAN	.800	.800	.800	.800	.800	.800	.800	.800
MINNESOTA	.800	.800	.800	.800	.800	.800	.800	.800
MISSISSIPPI	.800	.800	.800	.800	.800	.800	.800	.800
MISSOURI	.800	.800	.800	.800	.800	.800	.800	.800
MONTANA	.800	.800	.800	.800	.800	.800	.800	.800
NEBRASKA	.800	.800	.800	.800	.800	.800	.800	.800
NEVADA	.800	.800	.800	.800	.800	.800	.800	.800
NEW HAMPSHIRE	.800	.800	.800	.800	.800	.800	.800	.800
NEW JERSEY	.800	.800	.800	.800	.800	.800	.800	.800
NEW MEXICO	.800	.800	.800	.800	.800	.800	.800	.800
NEW YORK	.800	.800	.800	.800	.800	.800	.800	.800
NORTH CAROLINA	.800	.800	.800	.800	.800	.800	.800	.800
NORTH DAKOTA	.800	.800	.800	.800	.800	.800	.800	.800
OHIO	.800	.800	.800	.800	.800	.800	.800	.800
OKLAHOMA	.800	.800	.800	.800	.800	.800	.800	.800
OREGON	.800	.800	.800	.800	.800	.800	.800	.800
PENNSYLVANIA	.800	.800	.800	.800	.800	.800	.800	.800
RHODE ISLAND	.800	.800	.800	.800	.800	.800	.800	.800
SOUTH CAROLINA	.800	.800	.800	.800	.800	.800	.800	.800
SOUTH DAKOTA	.800	.800	.800	.800	.800	.800	.800	.800
TENNESSEE	.800	.800	.800	.800	.800	.800	.800	.800
TEXAS	.800	.800	.800	.800	.800	.800	.800	.800
UTAH	.800	.800	.800	.800	.800	.800	.800	.800
VERMONT	.800	.800	.800	.800	.800	.800	.800	.800
VIRGINIA	.800	.800	.800	.800	.800	.800	.800	.800
WASHINGTON	.800	.800	.800	.800	.800	.800	.800	.800
WEST VIRGINIA	.800	.800	.800	.800	.800	.800	.800	.800
WISCONSIN	.800	.800	.800	.800	.800	.800	.800	.800
WYOMING	.800	.800	.800	.800	.800	.800	.800	.800

TABLE A-5. PERCENT SULFUR CONTENT OF RESIDUAL OIL ELECTRIC UTILITIES

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	.000	.000	.000	.000	.000	.000	NA	.362
ARIZONA	1.269	1.269	1.269	1.269	1.269	.724	.769	.776
ARKANSAS	2.020	2.020	2.020	2.020	2.020	1.140	1.170	1.369
CALIFORNIA	.712	.712	.712	.712	.712	.410	.300	.330
COLORADO	1.202	1.202	1.202	1.202	1.202	1.173	.790	.534
CONNECTICUT	1.654	1.654	1.654	1.654	1.654	.422	.379	.430
DELAWARE	1.150	1.150	1.150	1.150	1.150	1.003	.796	1.006
DISTRICT OF COLUMBIA	2.994	2.994	2.994	2.994	2.994	.912	.927	.860
FLORIDA	1.009	1.009	1.009	1.009	1.009	1.635	1.290	1.492
GEORGIA	2.599	2.599	2.599	2.599	2.599	1.296	2.226	1.736
IDAHO	.000	.000	.000	.000	.000	.000	.000	.000
ILLINOIS	1.560	1.560	1.560	1.560	1.560	1.203	.676	.664
INDIANA	.217	.217	.217	.217	.217	.000	.000	.299
IOWA	2.292	2.292	2.292	2.292	2.292	.000	.223	.226
KANSAS	2.017	2.017	2.017	2.017	2.017	1.114	1.105	.493
KENTUCKY	.196	.196	.196	.196	.196	.000	.289	.362
LOUISIANA	NA	NA	NA	NA	NA	.711	.785	.843
MAINE	2.032	2.032	2.032	2.032	2.032	2.204	1.471	1.220
MARYLAND	1.645	1.645	1.645	1.645	1.645	1.350	1.261	1.260
MASSACHUSETTS	2.076	2.076	2.076	2.076	2.076	.731	1.577	1.750
MICHIGAN	1.026	1.026	1.026	1.026	1.026	.745	.703	.663
MINNESOTA	2.010	2.010	2.010	2.010	2.010	3.460	1.540	1.000
MISSISSIPPI	2.524	2.524	2.524	2.524	2.524	2.607	2.203	2.606
MISSOURI	1.606	1.606	1.606	1.606	1.606	1.791	1.263	.994
MONTANA	4.200	4.200	4.200	4.200	4.200	.000	.000	.277
NEBRASKA	7.155	7.155	7.155	7.155	7.155	1.135	1.203	.820
NEVADA	1.173	1.173	1.173	1.173	1.173	.732	.670	.720
NEW HAMPSHIRE	2.295	2.295	2.295	2.295	2.295	1.042	1.701	1.930
NEW JERSEY	1.021	1.021	1.021	1.021	1.021	.403	.430	.450
NEW MEXICO	.057	.057	.057	.057	.057	2.590	.520	1.000
NEW YORK	1.216	1.216	1.216	1.216	1.216	1.162	1.009	1.240
NORTH CAROLINA	NA	NA	NA	NA	NA	1.742	1.710	.232
NORTH DAKOTA	.036	.036	.036	.036	.036	.000	.200	.226
OHIO	.565	.565	.565	.565	.565	4.469	1.199	.530
OKLAHOMA	6.473	6.473	6.473	6.473	6.473	2.006	.000	.180
OREGON	1.700	1.700	1.700	1.700	1.700	6.600	[illegible]	.270
PENNSYLVANIA	1.329	1.329	1.329	1.329	1.329	.496	.612	.650
RHODE ISLAND	2.306	2.306	2.306	2.306	2.306	.932	.075	.940
SOUTH CAROLINA	3.156	3.156	3.156	3.156	3.156	1.999	1.956	1.036
SOUTH DAKOTA	.000	.000	.000	.000	.000	1.506	.090	.340
TENNESSEE	.000	.000	.000	.000	.000	.000	.000	.540
TEXAS	1.106	1.106	1.106	1.106	1.106	.746	.505	.495
UTAH	.071	.071	.071	.071	.071	.331	.294	.294 *
VERMONT	.300	.300	.300	.300	.300	.000	.000	.340
VIRGINIA	2.376	2.376	2.376	2.376	2.376	1.034	1.505	1.303
WASHINGTON	.100	.100	.100	.100	.100	.000	.000	1.630
WEST VIRGINIA	.250	.250	.250	.250	.250	.000	.200	.292
WISCONSIN	1.419	1.419	1.419	1.419	1.419	3.299	1.630	.410
WYOMING	.109	.109	.109	.109	.109	.000	.300	.301

* Default value

TABLE A-6. PERCENT SULFUR CONTENT OF RESIDUAL OIL INDUSTRIAL

STATES	1950	1955	1960	1965	1970	1975	1979	1980
ALABAMA	1.550	1.550	1.600	1.650	1.730	1.870	1.700	1.920
ARIZONA	2.010	2.010	1.930	1.620	1.850	1.530	1.400	1.510
ARKANSAS	1.420	1.420	1.530	1.590	1.760	1.590	1.510	1.670
CALIFORNIA	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
COLORADO	2.140	2.140	2.040	1.810	2.210	1.330	1.570	1.570
CONNECTICUT	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
DELAWARE	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
DISTRICT OF COLUMBIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
FLORIDA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
GEORGIA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
IDAHO	2.050	2.050	1.970	1.680	1.970	1.460	1.610	1.530
ILLINOIS	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
INDIANA	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
IOWA	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
KANSAS	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
KENTUCKY	1.410	1.410	1.450	1.500	1.560	1.450	1.330	1.540
LOUISIANA	1.650	1.550	1.500	1.650	1.730	1.870	1.700	1.920
MAINE	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
MARYLAND	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
MASSACHUSETTS	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
MICHIGAN	1.300	1.300	1.450	1.500	1.560	1.450	1.330	1.540
MINNESOTA	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
MISSISSIPPI	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
MISSOURI	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
MONTANA	2.140	2.140	2.040	1.810	2.210	1.330	1.570	1.570
NEBRASKA	1.760	1.760	1.790	1.690	1.990	1.410	1.510	1.580
NEVADA	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
NEW HAMPSHIRE	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
NEW JERSEY	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
NEW MEXICO	2.140	2.140	2.040	1.810	2.210	1.330	1.570	1.570
NEW YORK	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
NORTH CAROLINA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
NORTH DAKOTA	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
OHIO	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
OKLAHOMA	1.240	1.240	1.640	1.620	1.860	1.470	1.470	1.690
OREGON	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
PENNSYLVANIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
RHODE ISLAND	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
SOUTH CAROLINA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
SOUTH DAKOTA	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
TENNESSEE	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
TEXAS	1.655	1.655	1.650	1.670	1.860	1.640	1.600	1.750
UTAH	2.106	2.106	2.010	1.760	2.110	1.380	1.540	1.560
VERMONT	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
VIRGINIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
WASHINGTON	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
WEST VIRGINIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
WISCONSIN	1.300	1.300	1.540	1.500	1.770	1.500	1.450	1.590
WYOMING	2.140	2.140	2.040	1.810	2.210	1.380	1.570	1.570

TABLE A-7. PERCENT SULFUR CONTENT OF RESIDUAL OIL COMMERCIAL

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
ARIZONA	2.010	2.010	1.930	1.620	1.850	1.530	1.480	1.810
ARKANSAS	1.420	1.420	1.830	1.590	1.760	1.590	1.510	1.670
CALIFORNIA	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
COLORADO	2.140	2.140	2.040	1.810	2.210	1.330	1.570	1.570
CONNECTICUT	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
DELAWARE	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
DISTRICT OF COLUMBIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
FLORIDA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
GEORGIA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
IDAHO	2.050	2.050	1.970	1.680	1.970	1.460	1.810	1.530
ILLINOIS	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
INDIANA	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
IOWA	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
KANSAS	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
KENTUCKY	1.410	1.410	1.450	1.500	1.560	1.450	1.330	1.540
LOUISIANA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
MAINE	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
MARYLAND	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
MASSACHUSETTS	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
MICHIGAN	1.380	1.380	1.450	1.500	1.560	1.450	1.330	1.540
MINNESOTA	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
MISSISSIPPI	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
MISSOURI	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
MONTANA	2.140	2.140	2.040	1.810	2.210	1.330	1.570	1.570
NEBRASKA	1.760	1.760	1.790	1.690	1.990	1.410	1.510	1.500
NEVADA	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
NEW HAMPSHIRE	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
NEW JERSEY	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
NEW MEXICO	2.140	2.140	2.040	1.810	2.210	1.330	1.570	1.570
NEW YORK	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
NORTH CAROLINA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
NORTH DAKOTA	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
OHIO	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
OKLAHOMA	1.240	1.240	1.440	1.620	1.860	1.470	1.470	1.590
OREGON	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
PENNSYLVANIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
RHODE ISLAND	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
SOUTH CAROLINA	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
SOUTH DAKOTA	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
TENNESSEE	1.550	1.550	1.500	1.650	1.730	1.870	1.700	1.920
TEXAS	1.655	1.655	1.650	1.670	1.860	1.640	1.680	1.750
UTAH	2.106	2.106	2.010	1.760	2.110	1.380	1.540	1.560
VERMONT	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
VIRGINIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
WASHINGTON	1.970	1.970	1.890	1.560	1.730	1.600	1.460	1.500
WEST VIRGINIA	1.440	1.440	1.360	1.430	1.360	1.400	1.220	1.490
WISCONSIN	1.380	1.380	1.540	1.500	1.770	1.500	1.450	1.590
WYOMING	2.140	2.140	2.040	1.810	2.210	1.330	1.570	1.570

TABLE A-8. PERCENT SULFUR CONTENT OF DISTILLATE OIL ELECTRIC UTILITIES

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	.300	.300	.300	.300	.300	.160	.160	.160
ARIZONA	.300	.300	.300	.300	.300	.474	.474	.474
ARKANSAS	.300	.300	.300	.300	.300	.300	.300	.300 *
CALIFORNIA	.300	.300	.300	.300	.300	.267	.267	.267
COLORADO	.300	.300	.300	.300	.300	.200	.200	.200
CONNECTICUT	.300	.300	.300	.300	.300	.300	.300	.300 *
DELAWARE	.300	.300	.300	.300	.300	.300	.300	.300 *
DISTRICT OF COLUMBIA	.300	.300	.300	.300	.300	.200	.200	.200
FLORIDA	.300	.300	.300	.300	.300	.300	.300	.300 *
GEORGIA	.300	.300	.300	.300	.300	.220	.220	.220
IDAHO	.300	.300	.300	.300	.300	.300	.300	.300 *
ILLINOIS	.300	.300	.300	.300	.300	.107	.107	.107
INDIANA	.300	.300	.300	.300	.300	.364	.364	.364
IOWA	.300	.300	.300	.300	.300	.384	.384	.384
KANSAS	.300	.300	.300	.300	.300	.298	.298	.298
KENTUCKY	.300	.300	.300	.300	.300	.300	.300	.300 *
LOUISIANA	.300	.300	.300	.300	.300	.150	.150	.150
MAINE	.300	.300	.300	.300	.300	.300	.300	.300 *
MARYLAND	.300	.300	.300	.300	.300	.202	.202	.202
MASSACHUSETTS	.300	.300	.300	.300	.300	.300	.300	.300 *
MICHIGAN	.300	.300	.300	.300	.300	.632	.632	.632
MINNESOTA	.300	.300	.300	.300	.300	.300	.300	.300 *
MISSISSIPPI	.300	.300	.300	.300	.300	.300	.300	.300 *
MISSOURI	.300	.300	.300	.300	.300	.329	.329	.329
MONTANA	.300	.300	.300	.300	.300	.300	.300	.300 *
NEBRASKA	.300	.300	.300	.300	.300	.100	.100	.100
NEVADA	.300	.300	.300	.300	.300	.315	.315	.315
NEW HAMPSHIRE	.300	.300	.300	.300	.300	.100	.100	.100
NEW JERSEY	.300	.300	.300	.300	.300	.090	.090	.090
NEW MEXICO	.300	.300	.300	.300	.300	.070	.070	.070
NEW YORK	.300	.300	.300	.300	.300	.300	.300	.300 *
NORTH CAROLINA	.300	.300	.300	.300	.300	.236	.236	.236
NORTH DAKOTA	.300	.300	.300	.300	.300	.390	.390	.390
OHIO	.300	.300	.300	.300	.300	.269	.269	.269
OKLAHOMA	.300	.300	.300	.300	.300	.277	.277	.277
OREGON	.300	.300	.300	.300	.300	.300	.300	.300 *
PENNSYLVANIA	.300	.300	.300	.300	.300	.190	.190	.190
RHODE ISLAND	.300	.300	.300	.300	.300	.300	.300	.300 *
SOUTH CAROLINA	.300	.300	.300	.300	.300	.167	.167	.167
SOUTH DAKOTA	.300	.300	.300	.300	.300	.270	.270	.270
TENNESSEE	.300	.300	.300	.300	.300	.300	.300	.300 *
TEXAS	.300	.300	.300	.300	.300	.240	.240	.240
UTAH	.300	.300	.300	.300	.300	.300	.300	.300 *
VERMONT	.300	.300	.300	.300	.300	.300	.300	.300 *
VIRGINIA	.300	.300	.300	.300	.300	.191	.191	.191
WASHINGTON	.300	.300	.300	.300	.300	.300	.300	.300 *
WEST VIRGINIA	.300	.300	.300	.300	.300	.290	.290	.290
WISCONSIN	.300	.300	.300	.300	.300	.215	.215	.215
WYOMING	.300	.300	.300	.300	.300	.310	.310	.310

* Default value of 0.300 is used for all years

TABLE A-9. PERCENT SULFUR CONTENT OF DISTILLATE OIL INDUSTRIAL

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	.339	.339	.288	.169	.172	.193	.198	.220
ARIZONA	.464	.464	.465	.310	.239	.279	.256	.265
ARKANSAS	.332	.332	.302	.247	.254	.223	.222	.252
CALIFORNIA	.471	.471	.490	.313	.213	.274	.245	.257
COLORADO	.443	.443	.392	.303	.316	.296	.290	.290
CONNECTICUT	.325	.325	.249	.241	.210	.207	.219	.222
DELAWARE	.325	.325	.249	.241	.210	.207	.219	.222
DISTRICT OF COLUMBIA	.325	.325	.249	.241	.210	.207	.219	.222
FLORIDA	.339	.339	.255	.169	.172	.193	.198	.220
GEORGIA	.339	.339	.255	.169	.172	.193	.198	.220
IDAHO	.457	.457	.441	.300	.264	.285	.267	.273
ILLINOIS	.330	.330	.318	.273	.281	.233	.230	.263
INDIANA	.330	.330	.318	.273	.281	.233	.230	.263
IOWA	.330	.330	.318	.273	.281	.233	.730	.263
KANSAS	.330	.330	.318	.273	.281	.233	.230	.263
KENTUCKY	.400	.400	.404	.293	.245	.220	.224	.243
LOUISIANA	.339	.339	.255	.169	.172	.193	.198	.220
MAINE	.325	.325	.249	.241	.210	.207	.219	.222
MARYLAND	.325	.375	.249	.241	.210	.207	.219	.222
MASSACHUSETTS	.325	.325	.249	.241	.210	.207	.219	.222
MICHIGAN	.400	.400	.404	.293	.245	.220	.224	.243
MINNESOTA	.330	.330	.318	.273	.281	.233	.230	.263
MISSISSIPPI	.339	.339	.255	.169	.172	.233	.198	.220
MISSOURI	.330	.330	.318	.273	.281	.233	.230	.263
MONTANA	.443	.443	.392	.303	.316	.296	.290	.290
NEBRASKA	.306	.306	.355	.280	.290	.264	.260	.277
NEVADA	.471	.471	.490	.313	.213	.274	.245	.257
NEW HAMPSHIRE	.325	.325	.249	.241	.210	.207	.219	.222
NEW JERSEY	.325	.325	.249	.241	.210	.207	.219	.222
NEW MEXICO	.443	.443	.392	.303	.316	.296	.290	.290
NEW YORK	.325	.325	.249	.241	.210	.207	.219	.222
NORTH CAROLINA	.339	.339	.255	.169	.172	.193	.198	.220
NORTH DAKOTA	.330	.330	.318	.273	.281	.233	.230	.263
OHIO	.325	.325	.249	.241	.210	.207	.219	.222
OKLAHOMA	.352	.352	.332	.279	.288	.246	.242	.268
OREGON	.471	.471	.490	.313	.213	.274	.245	.257
PENNSYLVANIA	.325	.325	.249	.241	.210	.207	.219	.222
RHODE ISLAND	.325	.325	.249	.241	.210	.207	.219	.222
SOUTH CAROLINA	.339	.339	.255	.169	.172	.193	.198	.220
SOUTH DAKOTA	.330	.330	.318	.273	.281	.233	.230	.263
TENNESSEE	.339	.339	.255	.169	.172	.193	.198	.220
TEXAS	.362	.362	.305	.228	.235	.229	.229	.248
UTAH	.448	.448	.412	.305	.210	.292	.201	.283
VERMONT	.325	.325	.249	.241	.210	.207	.219	.222
VIRGINIA	.325	.325	.249	.241	.213	.207	.219	.222
WASHINGTON	.471	.471	.490	.313	.213	.274	.245	.257
WEST VIRGINIA	.325	.325	.249	.241	.210	.207	.219	.222
WISCONSIN	.330	.330	.318	.273	.281	.233	.230	.263
WYOMING	.443	.443	.392	.303	.316	.296	.290	.290

TABLE A-10. PERCENT SULFUR CONTENT OF DISTILLATE OIL COMMERCIAL-RESIDENTIAL

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	.339	.339	.256	.169	.172	.193	.190	.220
ARIZONA	.464	.464	.465	.310	.239	.279	.256	.265
ARKANSAS	.332	.332	.302	.247	.254	.223	.222	.252
CALIFORNIA	.471	.471	.490	.313	.213	.274	.245	.257
COLORADO	.443	.443	.392	.303	.316	.296	.290	.290
CONNECTICUT	.325	.325	.249	.241	.210	.207	.219	.222
DELAWARE	.325	.325	.249	.241	.210	.207	.219	.222
DISTRICT OF COLUMBIA	.325	.325	.249	.241	.210	.207	.219	.222
FLORIDA	.339	.339	.255	.169	.172	.193	.190	.220
GEORGIA	.339	.339	.256	.169	.172	.193	.190	.220
IDAHO	.457	.457	.441	.300	.264	.285	.267	.273
ILLINOIS	.330	.330	.310	.273	.201	.233	.230	.263
INDIANA	.330	.330	.310	.273	.201	.233	.230	.263
IOWA	.330	.330	.310	.273	.201	.233	.230	.263
KANSAS	.330	.330	.310	.273	.201	.233	.230	.263
KENTUCKY	.400	.400	.404	.293	.245	.220	.224	.243
LOUISIANA	.339	.339	.255	.169	.172	.193	.190	.220
MAINE	.325	.325	.249	.241	.210	.207	.219	.222
MARYLAND	.325	.325	.249	.241	.210	.207	.219	.222
MASSACHUSETTS	.325	.325	.249	.241	.210	.207	.219	.222
MICHIGAN	.400	.400	.404	.293	.245	.220	.224	.243
MINNESOTA	.330	.330	.310	.273	.201	.233	.230	.263
MISSISSIPPI	.339	.339	.255	.169	.172	.233	.190	.220
MISSOURI	.330	.330	.310	.273	.201	.233	.230	.263
MONTANA	.443	.443	.392	.303	.316	.296	.290	.290
NEBRASKA	.306	.306	.355	.280	.290	.264	.260	.277
NEVADA	.471	.471	.490	.313	.213	.274	.245	.257
NEW HAMPSHIRE	.325	.325	.249	.241	.210	.207	.219	.222
NEW JERSEY	.325	.325	.249	.241	.210	.207	.219	.222
NEW MEXICO	.443	.443	.392	.303	.316	.296	.290	.290
NEW YORK	.325	.325	.249	.241	.210	.207	.219	.222
NORTH CAROLINA	.339	.339	.255	.169	.172	.193	.190	.220
NORTH DAKOTA	.330	.330	.310	.273	.201	.233	.230	.263
OHIO	.325	.325	.249	.241	.210	.207	.219	.222
OKLAHOMA	.352	.352	.332	.279	.280	.246	.242	.260
OREGON	.471	.471	.490	.313	.213	.274	.245	.257
PENNSYLVANIA	.325	.325	.249	.241	.210	.207	.219	.222
RHODE ISLAND	.325	.325	.249	.241	.210	.207	.219	.222
SOUTH CAROLINA	.339	.339	.255	.169	.172	.193	.190	.220
SOUTH DAKOTA	.330	.330	.310	.273	.201	.233	.230	.263
TENNESSEE	.339	.339	.255	.169	.172	.193	.190	.220
TEXAS	.362	.362	.305	.220	.235	.229	.229	.240
UTAH	.440	.440	.412	.305	.210	.292	.201	.203
VERMONT	.325	.325	.249	.241	.210	.207	.219	.222
VIRGINIA	.325	.325	.249	.241	.213	.207	.219	.222
WASHINGTON	.471	.471	.490	.313	.213	.274	.245	.257
WEST VIRGINIA	.325	.325	.249	.241	.210	.207	.219	.222
WISCONSIN	.330	.330	.310	.273	.201	.233	.230	.263
WYOMING	.443	.443	.392	.303	.316	.296	.290	.290

TABLE A-11. PERCENT SULFUR CONTENT OF RAILROADS-COAL

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	1.610	1.610	1.650	1.650	1.200	1.059	1.049	1.049
ARIZONA	.000	.000	1.200	1.200	.500	.500	.512	.512
ARKANSAS	3.250	3.250	2.700	2.700	3.500	1.773	2.112	2.112
CALIFORNIA	.900	.900	.900	.900	.606	.606	.576	.576
COLORADO	.500	.500	1.000	1.000	.606	.742	.809	.809
CONNECTICUT	1.010	1.010	1.700	1.700	2.048	2.000	.000	.000
DELAWARE	1.630	1.630	1.600	1.600	1.930	.900	2.116	2.116
DISTRICT OF COLUMBIA	1.330	1.330	1.450	1.450	1.207	1.440	2.297	2.297
FLORIDA	1.520	1.520	1.650	1.650	1.200	1.200	1.130	1.130
GEORGIA	1.520	1.520	1.650	1.650	1.200	1.200	1.177	1.177
IDAHO	.870	.870	1.000	1.000	.661	.660	.693	.693
ILLINOIS	3.240	3.240	2.100	2.100	2.690	2.445	2.207	2.207
INDIANA	3.000	3.000	2.250	2.250	2.393	3.247	2.560	2.560
IOWA	3.500	3.500	2.550	2.550	2.713	2.653	1.934	1.934
KANSAS	2.920	2.920	2.650	2.650	3.500	1.700	2.101	2.101
KENTUCKY	2.670	2.670	2.000	2.000	3.171	1.742	1.644	1.644
LOUISIANA	3.250	3.250	2.700	2.700	3.500	.000	2.331	2.331
MAINE	1.350	1.356	1.600	1.600	1.670	2.344	1.100	1.100
MARYLAND	1.630	1.630	1.600	1.600	1.930	1.981	2.345	2.345
MASSACHUSETTS	1.550	1.550	1.300	1.300	1.503	2.045	1.793	1.793
MICHIGAN	2.190	2.190	1.750	1.750	1.701	1.557	1.027	1.027
MINNESOTA	2.210	2.210	1.950	1.950	1.942	2.121	1.069	1.069
MISSISSIPPI	1.610	1.610	1.650	1.650	1.200	1.055	2.507	2.507
MISSOURI	3.390	3.390	2.459	2.450	2.795	2.685	2.467	2.467
MONTANA	.870	.870	1.000	1.000	.661	.685	.698	.698
NEBRASKA	2.920	2.920	2.550	2.550	3.500	.808	.700	.700
NEVADA	.000	.000	1.200	1.200	.500	.590	.600	.600
NEW HAMPSHIRE	1.350	1.350	1.600	1.600	1.670	2.000	2.100	2.100
NEW JERSEY	1.500	1.500	1.750	1.750	1.607	2.642	1.505	1.505
NEW MEXICO	.850	.850	1.200	1.200	.500	.000	.575	.575
NEW YORK	1.620	1.620	1.650	1.650	1.881	2.059	2.103	2.103
NORTH CAROLINA	1.420	1.420	1.150	1.150	1.200	.901	1.103	1.103
NORTH DAKOTA	.400	.400	1.100	1.100	.611	.600	.700	.700
OHIO	2.520	2.520	2.300	2.300	2.453	2.109	2.511	2.511
OKLAHOMA	3.250	3.250	2.700	2.700	3.500	1.411	2.107	2.107
OREGON	.810	.810	.000	.000	.550	.685	.773	.773
PENNSYLVANIA	1.760	1.760	1.650	1.650	2.060	1.008	2.112	2.112
RHODE ISLAND	1.350	1.350	1.600	1.600	1.670	2.000	1.000	1.000
SOUTH CAROLINA	1.450	1.450	1.203	1.200	1.200	.900	1.099	1.099
SOUTH DAKOTA	.400	.400	1.100	1.100	.611	.676	.702	.702
TENNESSEE	1.010	1.010	1.900	1.900	1.860	1.408	1.951	1.951
TEXAS	3.250	3.250	2.700	2.700	3.500	1.633	1.792	1.792
UTAH	.000	.000	1.050	1.050	.537	.602	.608	.608
VERMONT	1.350	1.350	1.600	1.600	1.670	2.000	2.100	2.100
VIRGINIA	1.330	1.330	1.200	1.200	1.200	.881	1.140	1.140
WASHINGTON	.810	.810	.000	.000	.550	.611	.670	.670
WEST VIRGINIA	1.550	1.550	1.950	1.950	1.403	1.620	1.737	1.737
WISCONSIN	2.010	2.010	1.900	1.900	2.131	1.851	2.065	2.065
WYOMING	.020	.020	1.150	1.150	.700	.700	.697	.697

TABLE A-12. PERCENT SULFUR CONTENT OF COKE PLANTS

STATES	1950	1955	1960	1965	1970	1975	1978	1980
ALABAMA	1.550	1.550	1.100	1.100	.890	.969	.935	.935
ARIZONA	.000	.000	.000	.000	.000	.000	.000	.000
ARKANSAS	1.570	1.570	.000	.000	.800	.000	.000	.000
CALIFORNIA	1.720	1.720	.700	.700	.700 *	.700 *	.743	.743
COLORADO	.500	.500	.700	.700	.709	.699	.683	.683
CONNECTICUT	1.200	1.200	1.000	1.000	.000	.000	.000	.000
DELAWARE	.000	.000	.000	.000	.000	.000	.000	.000
DISTRICT OF COLUMBIA	.000	.000	.000	.000	.000	.003	.000	.000
FLORIDA	.000	.000	.000	.000	.000	.000	.000	.000
GEORGIA	.000	.000	.000	.000	.000	.000	.000	.000
IDAHO	.000	.000	.000	.000	.050	.000	.000	.000
ILLINOIS	1.550	1.550	.700	.700	.000	.596	.883	.883
INDIANA	1.200	1.200	.700	.700	.000	.841	.869	.869
IOWA	.000	.000	.000	.000	.005	.000	.000	.000
KANSAS	.000	.000	.000	.000	.000	.000	.000	.000
KENTUCKY	1.360	1.360	1.000	1.000	.800	.877	.790	.790
LOUISIANA	1.570	1.570	1.000 *	.000	.000	.003	.000	.000
MAINE	.000	.000	.000	.000	.000	.000	.000	.000
MARYLAND	2.760	2.760	1.000	1.000	.006	.772	1.097	1.097
MASSACHUSETTS	1.340	1.340	1.300 *	.000	.000	.000	.000	.000
MICHIGAN	1.390	1.390	.000	.000	.900	.425	.802	.802
MINNESOTA	1.350	1.350	.000	.000	.888	.830	.748	.748
MISSISSIPPI	.000	.000	.000	.000	.000	.000	.000	.000
MISSOURI	1.000 *	1.600 *	1.000	1.000	.800	.794	.772	.772
MONTANA	.000	.000	.000	.000	.000	.000	.000	.000
NEBRASKA	.000	.600	.000	.000	.000	.000	.000	.000
NEVADA	.000	.000	.000	.000	.000	.000	.000	.000
NEW HAMPSHIRE	.000	.000	.000	.000	.000	.000	.000	.000
NEW JERSEY	1.470	1.470	1.000	1.000	1.300	.000	.000	.000
NEW MEXICO	.000	.000	.000	.000	.000	.000	.000	.000
NEW YORK	1.010	1.010	1.000	1.000	1.291	.969	1.005	1.005
NORTH CAROLINA	.000	.000	.000	.000	.000	.000	.000	.000
NORTH DAKOTA	.000	.000	.000	.000	.000	.000	.000	.000
OHIO	1.540	1.540	1.100	1.100	.996	1.061	.929	.929
OKLAHOMA	.000	.000	.000	.000	.000	.000	.000	.000
OREGON	.000	.000	.000	.000	.000	.000	.000	.000
PENNSYLVANIA	1.740	1.740	1.300	1.300	1.104	1.195	1.101	1.101
RHODE ISLAND	.000	.000	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	.000	.000	.000	.000	.000	.006	.000	.000
SOUTH DAKOTA	.000	.000	.000	.000	.000	.000	.000	.000
TENNESSEE	1.470	1.470	1.000	1.000	.800	.900	1.236	1.236
TEXAS	1.570	1.570	1.000	1.000	.800	.805	.909	.909
UTAH	.500	.500	.700	.700	.700 *	.700 *	.689	.689
VERMONT	.000	.000	.000	.000	.000	.000	.000	.000
VIRGINIA	1.470	1.470	.600	.600	.800	.000	.700	.700
WASHINGTON	.000	.000	.000	.000	.000	.000	.000	.000
WEST VIRGINIA	1.000	1.000	1.200	1.200	1.034	1.236	.956	.956
WISCONSIN	1.330	1.330	.000	.000	.000	.000	.041	.041
WYOMING	.000	.000	.000	.000	.000	.000	.000	.000

APPENDIX B

EMISSION FACTORS FOR HIGHWAY VEHICLES AND CEMENT PLANTS

LIST OF TABLES

Table Page

SO_2 Emission Factors for Highway Vehicles. B-1

NO_x Emission Factors for Rural Highway Vehicles. B-2

NO_x Emission Factors for Urban Highway Vehicles. B-3

SO_2 Emission Factors by State for Cement Plants. B-4

TABLE B-1. SO2 EMISSION FACTORS FOR HIGHWAY VEHICLES

STATE	1950[a]	1955	1960	1965	1970	1975	1978	1980
	10^{-6} tons/gal				10^{-3} tons/mi			
ALABAMA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
ARIZONA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
ARKANSAS	2.410	2.348	2.041	2.048	.160	.158	.159	.161
CALIFORNIA	2.410	2.344	2.041	2.048	.160	.158	.159	.161
COLORADO	2.410	2.348	2.041	2.048	.160	.158	.159	.161
CONNECTICUT	2.410	2.348	2.041	2.048	.160	.158	.159	.161
DELAWARE	2.410	2.348	2.041	2.048	.160	.158	.159	.161
DISTRICT OF COLUMBIA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
FLORIDA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
GEORGIA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
IDAHO	2.410	2.348	2.041	2.048	.160	.158	.159	.161
ILLINOIS	2.410	2.348	2.041	2.048	.160	.158	.159	.161
INDIANA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
IOWA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
KANSAS	2.410	2.348	2.041	2.048	.160	.158	.159	.161
KENTUCKY	2.410	2.348	2.041	2.048	.160	.158	.159	.161
LOUISIANA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MAINE	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MARYLAND	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MASSACHUSETTS	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MICHIGAN	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MINNESOTA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MISSISSIPPI	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MISSOURI	2.410	2.348	2.041	2.048	.160	.158	.159	.161
MONTANA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NEBRASKA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NEVADA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NEW HAMPSHIRE	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NEW JERSEY	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NEW MEXICO	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NEW YORK	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NORTH CAROLINA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
NORTH DAKOTA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
OHIO	2.410	2.348	2.041	2.048	.160	.158	.159	.161
OKLAHOMA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
OREGON	2.410	2.348	2.041	2.048	.160	.158	.159	.161
PENNSYLVANIA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
RHODE ISLAND	2.410	2.348	2.041	2.048	.160	.158	.159	.161
SOUTH CAROLINA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
SOUTH DAKOTA	2.410	2.348	2.041	2.048	.160	.158	.159	.151
TENNESSEE	2.410	2.348	2.041	2.048	.160	.158	.159	.161
TEXAS	2.410	2.348	2.041	2.048	.160	.158	.159	.161
UTAH	2.410	2.348	2.041	2.048	.160	.158	.159	.161
VERMONT	2.410	2.348	2.041	2.048	.160	.158	.159	.161
VIRGINIA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
WASHINGTON	2.410	2.348	2.041	2.048	.160	.158	.159	.161
WEST VIRGINIA	2.410	2.348	2.041	2.048	.160	.158	.159	.161
WISCONSIN	2.410	2.348	2.041	2.048	.160	.158	.159	.161
WYOMING	2.410	2.348	2.041	2.048	.160	.158	.159	.161

a Same emission factors are used for all earlier years.

TABLE B-2. NOX EMISSION FACTORS (10E-6 TONS/GAL) FOR RURAL HIGHWAY VEHICLES

STATE	1950[a]	1955	1960	1965	1970	1975	1978	1980
	BASED ON FUEL CONSUMPTION				BASED ON VMT			
ALABAMA	5.012	4.896	4.775	4.756	4.937	4.327	4.350	3.928
ARIZONA	4.911	4.806	4.695	4.681	4.803	4.803	4.330	3.910
ARKANSAS	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
CALIFORNIA	5.012	4.896	4.775	4.515	4.551	4.260	3.816	3.419
COLORADO	3.608	3.609	3.608	3.623	3.903	4.161	3.770	3.400
CONNECTICUT	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
DELAWARE	5.012	4.896	4.775	4.663	4.937	4.827	4.350	3.908
DISTRICT OF COLUMBIA	5.012	4.896	4.775	4.663	4.937	4.827	4.350	3.908
FLORIDA	5.012	4.896	4.775	4.663	4.937	4.827	4.350	3.908
GEORGIA	5.012	4.896	4.775	4.663	4.937	4.827	4.350	3.908
IDAHO	4.670	4.582	4.488	4.479	4.704	4.665	4.200	3.799
ILLINOIS	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
INDIANA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
IOWA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
KANSAS	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
KENTUCKY	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
LOUISIANA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MAINE	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MARYLAND	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MASSACHUSETTS	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MICHIGAN	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MINNESOTA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MISSISSIPPI	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MISSOURI	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
MONTANA	4.649	4.564	4.472	4.464	4.691	4.656	4.201	3.791
NEBRASKA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
NEVADA	4.720	4.636	4.530	4.527	4.744	4.693	4.232	3.821
NEW HAMPSHIRE	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
NEW JERSEY	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
NEW MEXICO	3.608	3.609	3.608	3.623	3.903	4.161	3.770	3.400
NEW YORK	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
NORTH CAROLINA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
NORTH DAKOTA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
OHIO	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
OKLAHOMA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
OREGON	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
PENNSYLVANIA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
RHODE ISLAND	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
SOUTH CAROLINA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
SOUTH DAKOTA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
TENNESSEE	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
TEXAS	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
UTAH	3.608	3.609	3.600	3.623	3.903	4.161	3.770	3.400
VERMONT	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
VIRGINIA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
WASHINGTON	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
WEST VIRGINIA	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
WISCONSIN	5.012	4.896	4.775	4.756	4.937	4.827	4.350	3.928
WYOMING	3.608	3.609	3.600	3.623	3.903	4.161	3.770	3.400

a Same emission factors are used for all earlier years.

TABLE 8-3. NOX EMISSION FACTORS (10E-6 TONS/GAL) FOR URBAN HIGHWAY VEHICLES

[illegible]	[illegible]	1960	1965	1970	1975	1978	1980
[illegible] CONSUMPTION				BASED ON VMT			
[illegible]	[illegible]	[illegible]	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	[illegible]	4.162	4.400	4.346	3.875	3.561
[illegible]	[illegible]	[illegible]	[illegible]	4.544	4.476	3.978	3.647
[illegible]	[illegible]	[illegible]	[illegible]	4.209	4.091	3.899	3.261
[illegible]	[illegible]	[illegible]	2.691	2.987	3.068	2.856	2.709
[illegible]	[illegible]	[illegible]	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	[illegible]	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	[illegible]	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.036	4.017	4.270	4.228	3.781	3.402
[illegible]	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	4.300	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	4.300	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	4.300	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	4.300	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	4.300	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	[illegible]	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	4.073	4.032	4.014	4.266	4.225	3.779	3.400
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
[illegible]	4.004	3.966	3.950	4.204	4.169	3.733	3.443
[illegible]	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
2.636	2.653	2.666	2.691	2.987	3.068	2.856	2.709
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
2.636	2.653	2.666	2.691	2.987	3.068	2.856	2.709
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
4.430	4.300	4.320	4.300	4.544	4.476	3.978	3.647
2.636	2.653	2.666	2.691	2.987	3.068	2.856	2.709

a Same emission factors are used for all earlier years.

TABLE B-4. SO2 EMISSION FACTORS BY STATE FOR CEMENT PLANTS (LB/TON)[a]

STATES	1950[b]	1955	1960	1965	1970	1975	1978	1980
ALABAMA	14.303	14.303	14.366	14.473	13.607	15.100	13.053	14.010
ARIZONA	11.270	11.270	11.670	11.670	10.012	10.200	10.200	10.200
ARKANSAS	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
CALIFORNIA	11.057	11.057	11.022	10.879	10.953	10.096	10.035	10.052
COLORADO	11.072	11.072	12.000	12.073	11.077	12.075	12.091	12.091
CONNECTICUT	.000	.000	.000	.000	.000	.000	.000	.000
DELAWARE	.000	.000	.000	.000	.000	.000	.000	.000
DISTRICT OF COLUMBIA	.000	.000	.000	.000	.000	.000	.000	.000
FLORIDA	17.289	17.289	17.309	17.339	17.630	16.010	16.209	10.301
GEORGIA	14.389	14.389	14.287	14.671	14.011	15.127	14.720	15.204
IDAHO	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
ILLINOIS	23.072	23.072	20.101	20.101	19.910	10.121	10.579	10.579
INDIANA	23.968	23.968	25.612	25.612	22.263	29.601	23.955	23.955
IOWA	29.585	29.585	27.667	27.667	19.756	16.612	22.167	22.167
KANSAS	11.713	11.713	12.457	12.457	13.297	10.200	12.050	12.050
KENTUCKY	23.641	23.641	22.778	22.705	22.644	10.076	10.928	10.955
LOUISIANA	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
MAINE	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
MARYLAND	10.200	10.200	10.200	10.200	10.200	10.200	10.200	19.200
MASSACHUSETTS	.000	.000	.000	.000	.000	.000	.000	.000
MICHIGAN	19.721	19.721	22.187	22.187	19.537	16.269	23.373	23.373
MINNESOTA	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
MISSISSIPPI	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
MISSOURI	21.654	21.654	10.652	10.652	20.543	19.411	10.100	10.100
MONTANA	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
NEBRASKA	13.235	13.235	14.726	14.726	14.412	11.442	11.442	11.442
NEVADA	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
NEW HAMPSHIRE	.000	.000	.000	.000	.000	.000	.000	.000
NEW JERSEY	.000	.000	.000	.000	.000	.000	.000	.000
NEW MEXICO	10.296	10.296	10.292	10.201	10.299	10.260	10.271	10.271
NEW YORK	16.320	16.320	15.900	16.277	15.900	16.150	15.385	16.532
NORTH CAROLINA	19.047	19.047	17.633	17.797	10.136	16.779	17.112	17.353
NORTH DAKOTA	.000	.000	.000	.000	.000	.000	.000	.000
OHIO	24.242	24.242	25.955	25.955	25.011	27.209	20.044	20.044
OKLAHOMA	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
OREGON	10.200	10.200	10.200	10.200	10.200	10.200	10.200	10.200
PENNSYLVANIA	21.926	21.926	20.333	20.393	23.107	10.440	22.633	22.061
RHODE ISLAND	.000	.000	.000	.000	.000	.000	.000	.000
SOUTH CAROLINA	10.921	10.921	10.897	10.967	11.004	11.070	10.990	11.093
SOUTH DAKOTA	10.230	10.200	10.200	10.200	10.200	10.200	10.200	10.200
TENNESSEE	29.660	29.660	22.483	22.483	10.967	16.200	20.156	20.156
TEXAS	10.539	10.539	10.537	10.537	10.450	10.200	10.200	10.450
UTAH	11.705	11.705	11.700	11.789	10.952	11.106	11.105	11.105
VERMONT	.000	.000	.000	.000	.000	.000	.000	.000
VIRGINIA	10.694	10.694	10.420	10.420	10.460	16.207	17.454	17.454
WASHINGTON	13.191	13.191	13.007	12.650	12.720	12.618	12.396	12.448
WEST VIRGINIA	10.200	10.200	10.200	10.200	10.200	19.200	10.200	10.200
WISCONSIN	16.065	16.065	16.745	16.915	17.722	16.575	16.362	16.957
WYOMING	15.200	15.200	10.077	10.077	14.995	14.995	14.968	14.968

[a] Based on individual plant capacity and fuel type used as reported in Reference 35. An average statewide emission factor is then calculated for each state according to state production.

[b] Same emission factors are used for all earlier years.

Senator **Evans**. Well, that will be helpful.

Are you aware at this moment of whether there are some significant differences on an areawide basis, or is it pretty uniform?

Mr. **Hodel**. I am not.

Mr. **Ruckelshaus**. There are significant uniform downturns. It has been true in the Ohio Valley, which is the question—the area most in question here, that there have been downturns in sulfur oxide emissions since the middle of the last decade.

Mr. **Hodel**. An interesting aspect of that last figure, Senator, is that in 1982, it turned out that the emissions were as low as we had projected could possibly occur under either of two somewhat-argued-about models by 1998, which is a very encouraging sign, not necessarily indicative of the future trendline.

Senator **Evans**. It's either an encouraging sign, or we have faulty models.

Mr. **Hodel**. The historical is not a faulty model. The models are probably faulty as they look to the future. That we could agree on.

But that was the most optimistic model and we're already—according to this indication—at the 1998 level.

Senator **Evans**. Both you and Mr. Ruckelshaus mentioned the raised cost, and that unquestionably is a problem, and it's going to be a very difficult one.

I'm a little concerned, however, because if you extend the concept of broadening the cost beyond those who create the pollutants, are we going to ask bus and bicycle riders, for instance, to pay for automobile emission controls? Are we going to ask all citizens to pay for the industrial controls on water pollution that we previously had asked the industries themselves who create the pollution to pay for?

It seems to me we're embarking on a direction that would be a new and almost endless one.

And that goes along with another thing—that it seems to me—that this administration has supported rather vigorously, and that's the concept that deregulation, and especially deregulation on a variety of fuels is a good thing, let it seek its own reasonable price, and people can make their economic decisions based on price.

Shouldn't all sources carry their own direct environmental costs, and in doing so, allow us to have a more accurate measurable idea of what the true cost of producing energy from that source is, so that people can make a reasonable economic choice?

Mr. **Hodel**. Senator, I think that's a theoretically sound principle, which I think we generally do espouse. The user pays, essentially, is a sound approach. The problems in a society, of course, are multiple, not only vested interest concerns and the impact on them if changes are made in any rapid fashion, but, secondarily, the matter of measuring the cost burdens and benefits, which is a part of the argument here, as to whether there are benefits to be achieved, anything approaching the cost.

I think that, as long as that is in dispute, it will be very difficult to determine how much could fairly or properly be spent.

Senator **Evans**. Well, I understand that. I have no quarrel with that.

Mr. **Hodel**. The principle's sound.

Senator **Evans**. It's just once you decide how much is to be spent it's who pays.

Mr. **Hodel**. The principle there, in my view, is that it ought to be the user who pays. If we go into any other system, we find ourselves deciding consciously that we are going to subsidize a particular activity. We do this all over the lot, I acknowledge, as a society. But I'm saying it would be a sounder approach here to have the particular energy system that produces the pollutant, bear the cost of preventing it.

Senator **Evans**. Well, I thought that that was one of the bastions of this administration's philosophy, and I think it's a good one.

The **Chairman**. Thank you very much, Senator Evans.

Senator **Evans**. Thank you, Mr. Chairman.

The **Chairman**. Senator Ford.

Senator **Ford**. Thank you, Mr. Chairman.

Mr. Hodel, since you need to move, I'll try to ask your questions. I only have two, and one is a statement.

As relates to an earlier question about $100 million for the Coal Technology Demonstration Program, I submitted that for the record. So you will know where it came from. It came out of inside Energy, and it was your telephone call to a Congressman from Pennsylvania. So we clear it up and you won't go out of here wondering how in the world that ever got out. Ford's the culprit.

Mr. **Hodel**. Thank you.

[Subsequently, the following contract from the April 19, 1984, issue of Inside Energy was submitted for the record.]

[From Inside Energy/With Federal Lands, Apr. 4, 1984]

HODEL PLANS TO REVIEW $100-MILLION COAL-TECHNOLOGY DEMONSTRATION PROGRAM

Energy Secretary Donald Hodel, in a move some observers read as DOE's willingness to fill a perceived gap in fossil-energy r&d, told a Pennsylvania congressman last week that he was "strongly interested" in a proposed $100-million increase in coal-related r&d, a DOE spokesperson said. Hodel telephoned Rep. Doug Walgren, D-Pa., early last week to congratulate him after the House Energy subcommittee on fossil and synthetic fuels adopted Walgren's amendment to boost FY-85 and FY-86 r&d funds by $100 million to finance cost-utilization and environmental-engineering demonstrations on a cost-shared basis with industry. Hodel promised, the DOE official said, "to review the amendment fully and, if appropriate, to go to the Office of Management and Budget" with a request for the funds.

Walgren's amendment was adopted as part of legislation authorizing $5.4 billion for DOE's non-defense R&D and related programs in FY-85 and in FY-86 (H.R. 5048). The subcommittee completed its markup of the bill. It will now be considered by the full Energy and Commerce Committee, but not until after natural-gas legislation has been moved, according to a subcommittee staffer.

Walgren, according to a spokesman, took the Hodel call as a signal that DOE was ready to support his proposal, which Walgren had discussed earlier with William Vaughan, DOE assistant secretary for fossil energy. The incentive for DOE support is a cost-sharing provision that would be mandated by the amendment. It would, for the first time, codify the cost-sharing principle embraced by OMB as a condition for federal support of costly demonstration projects and pilot plants. An official in Vaughan's office said DOE "would like to see a policy of 50% or more" cost-sharing by industry in such projects. "Our experience is that cost-sharing brings projects in closer to schedule and closer to budget than those that don't have such provisions," the official said.

Walgren's national coal-engineering program would be administered by DOE's energy technology centers. Industry would be able to apply for assistance in the construction of semiworks, or demonstrations, of environmental-control engineering technologies and utilization technologies. The environmental technologies eligible include:

Fine-coal preparation and cleaning, including chemical coal cleaning at a scale of not more than 500 tons/day

Retrofits of oil boilers of not less than 100 megawatts capacity, using coal cleaned with various technologies

Retrofits of oil boilers of less than 100 Mw capacity, using a coal-water mixture

Advanced regenerable flue gas cleanup on existing coal-fired plants of between 20 Mw and 100 Mw

Combined sulfur dioxide/nitrogen oxide removal from coal-fired plants of 20 Mw to 100 Mw

Advanced combustion modification for high nitrogen-oxide reduction on coal-fired plants of not less than 50 Mw

Retrofit application of in-boiler sulfur control on existing coal-fired facilities of not less than 50 Mw. In utilization technologies, assistance could be provided for any of the following:

Repowering application of combined-cycle coal gasification of 50 Mw to 100 Mw

Coal-fueled gas turbine in second-generation combined-cycle systems of not less than 50 Mw

Industrial-scale coal-fueled gas turbines suitable for cogeneration of not less than 5 Mw

Integrated magnetohydrodynamics systems tests, including generators and downstream-steam plants with superconducting magnets

Advanced direct coal liquefaction at a scale of 5 tons to 10 tons of coal per day

Advanced indirect coal liquefaction at a scale of 5 tons to 10 tons of coal per day

DOE would also be charged under Walgren's amendment with preparing a five-year national coal engineering research plan that would point to opportunities for coal use in the residential, commercial, industrial and electric-utility sectors, with DOE plans for meeting such opportunities, priorities for achieving such objectives and the resources needed to complete such a plan. DOE would have to complete an annual report in FY-85 and FY-86 on the coal engineering program.

Senator FORD. And then one other question as it relates to cost. Won't it be basically the reliability of the utility generating the electricity as it relates to the cost?

Mr. HODEL. It would be reliability, plus there's a penalty of production as well if scrubbers are installed, Senator. There's a reduced production capability from the powerplant that is used to drive the scrubbers, as well as the reduced reliability.

Senator FORD. Well, it would be the reliability of the region that uses the electricity produced by that source, will it not?

Mr. HODEL. It will generally be there. I have to qualify, because we have fairly strongly interconnected regions, so there is some available assistance between regions, but ordinarily the reliability impacts are on the utility that has the facility initially and its related utility adjacent to it.

Senator FORD. I thank you, Mr. Secretary.

Mr. Administrator, I asked Senator Mitchell earlier, and if you do not have the answer I hope you would submit it for the record. What would be the effect of taking 1973, which was the peak emission year, as the base year in Senator Mitchell's legislation and reducing the SO_2 emission level to that of the level proposed in his legislation?

Mr. RUCKELSHAUS. Your question relates to giving credit to those who have already done something about the——

Senator FORD. That is correct; yes, sir.

Mr. RUCKELSHAUS. Well, there are a lot of ways in which that can be done; one of which is to take 1973 as the base year—and I think we have that data and we would be glad to submit it to you, Senator.

Senator FORD. If you would do that, I would appreciate it.

Then one other question—or several other questions, as long as my time allows me.

The Senate Environment Committee bill calls for a 10-million-ton reduction in annual SO_2 emissions within 31 easternmost States.

That is almost a 50-percent, as I see it, reduction in the emissions for those particular States.

Can you, as the Administrator, assure us that the reduction will achieve a 50-percent reduction in acid deposition? Can we be assured that it will reduce the damage from acid deposition by a comparable amount?

Mr. RUCKELSHAUS. Well, about all you can assure is that by quoting some of the scientific groups which have looked at it, Senator. And there is some disagreement about the linear effect, or linear relationship between SO_2 emissions and sulfate deposition.

The National Academy of Sciences, which has been quoted widely here earlier in this hearing in a double negative, indicated they cannot now prove that the relationship is not linear. And what they really were saying was that over that same 31-State region, on an average, you would get a 50-percent reduction in sulfate deposition if the relationship is linear, as they suspect it is.

Now, that doesn't mean that in a targeted area, such as the Northeast, you would get a 50-percent reduction in sulfate deposition; quite the contrary, there may be some variation between the amount of reduction you'd get in a given geographic region and another one. And you might not hit the right targeted area, of course, which is one of the problems.

Senator FORD. On page 4 of your statement you make the general observation, I think, that we really don't know what the offending pollutants are.

It has been suggested to me that there may be a problem with the emissions from catalytic converters now mandated on automobiles. The noxious oxides causing smog have been curtailed, but emissions now contain sulfur oxides which, when combined with the moisture, form sulfur acids, the same as sulfur oxides from stationary sources.

In your opinion, from the information you have, is that statement true?

Mr. RUCKELSHAUS. The question about which pollutant is the culprit, whether it's nitrogen oxides or sulfur oxides for acid deposition; the question on page 4 really relates more to the culprit in terms of forest damage as opposed to the lake damage.

We do know that acid deposition—we do know—there is a consensus that acid deposition is about 70 percent result of sulfur oxides, 30 percent nitrogen oxides in this country.

The primary source of sulfur oxide emissions in this country are powerplants, again about 70 percent, 30 percent industrial facilities and others. And the contribution of the automobile, while there may be some contribution, is not assumed to be all that great for sulfur oxide.

Now, nitrogen oxide, mobile sources are approximately half the contribution.

Senator FORD. Well, does EPA have limits on these sulfur oxide emissions?

Mr. RUCKELSHAUS. We have limits on emissions from the automobile that relate to three pollutants, carbon monoxide, hydrocarbons, and nitrogen oxide. Smog oxidants is a result of the combination of hydrocarbons and nitrogen oxides in sunlight.

The control over oxidants, photochemical oxidants is a result of our controls on both hydrocarbons and nitrogen oxide.

Senator FORD. Well, do you have a comparison of the sulfur oxides emitted by cars to the sulfur oxide emitted by stationary sources?

Mr. RUCKELSHAUS. We'd be glad to supply that. I would hate to give that off the top of my head, but I'd be glad to supply that for the record, sir.

Senator FORD. If you'd do that, I would be grateful to you.

Would it be a fantasy to think that by chance the EPA has advocated a process for controlling smog that contributes further problems to acid rain?

Mr. RUCKELSHAUS. It may not be a fantasy, but I don't know that the—unless you relate the catalytic converter on the automobile to an increase in sulfate deposition——

Senator FORD. I thought that's where I was leading you to.

Mr. RUCKELSHAUS. To whatever extent that relationship can be made, that correlation can be made, then the fantasy would become a reality.

But again, I would hate to suggest off the top of my head there was no substance to that, but let me submit it for the record, Senator, so that it's clear what our position is.

Senator FORD. All right.

Mr. Administrator, by letter, I'm going to ask the chairman of this committee if he will address my inquiries to the Office of Technology Assessment. I believe that in this whole controversy our attention has been diverted toward emissions from stationary sources alone. We may be in danger of making a mistake, and I think it is time that we take a long, hard look at the role of mobile sources as major contributors to the creation of acid rain.

While I'm on the subject of other contributors to acid rain, Mr. Administrator, how closely is EPA studying the use of oil as one of the principal causes of the problems in New York and New England?

Mr. RUCKELSHAUS. We are trying to assess, through both the fuel-use numbers that we have, and our emission numbers which come from the State, emissions of sulfur oxides, what the source of those emissions are on a State-by-State basis, Senator. We have quite a bit of information that relates to what the source of sulfur oxides is in any given State.

Senator FORD. Thank you. I understand my time is up.

Mr. Hill, I had a question of you. You've been left out, and I didn't want you to feel lonesome, but I'll get to you.

The CHAIRMAN. When he says he'll get to you, he will. [Laughter.]

I understand Secretary Hodel has to leave, and before recognizing Senator Hecht, might I ask just one question of each of the three witnesses, an identical question, so that all three of you can be on the record at the same time with respect to the same question.

The administration has suggested that there are substantial uncertainties with respect to what the scope of the problem is, but perhaps more importantly, what the solution might be. I think that's a fair summary of what the administration has suggested. That we should do more research to determine both the source of the problem and the scope of the problem, but perhaps, more importantly, how do you deal with the problem.

Do you, Secretary Hodel, have any hesitancy in supporting that position of the administration?

Mr. HODEL. Personally, I have no personal problem with that at all, Senator. I think it is absolutely justified by what I see in the record at this time.

The CHAIRMAN. Mr. Ruckelshaus?

Mr. RUCKELSHAUS. I've testified to that effect now, and this is the third committee in which I have presented substantially testimony as you just suggested, Senator.

The CHAIRMAN. Mr. Hill?

Mr. HILL. Mr. Chairman, I support that very strongly, and this is after review of the literature and some personal contemplation and discussion with my colleagues.

The CHAIRMAN. One followup, again, of all three.

I assume—and I don't mean to place words in your mouth, and if you have any disagreement with this statement, please feel free to say so. But I assume that position of the administration includes also an opposition to enactment of S. 768, Senator Mitchell's bill. Mr. Hodel.

Mr. HODEL. As I understand the bill, I think it would, yes, necessarily.

The CHAIRMAN. Mr. Ruckelshaus?

Mr. RUCKELSHAUS. Yes, it does. We're not prepared to recommend any SO_2 control program at this time, Senator.

The CHAIRMAN. Mr. Hill?

Mr. HILL. That goes for me also.

The CHAIRMAN. Thank you very much.

Senator Hecht, do you have any questions of Secretary Hodel?

Senator HECHT. One brief question for you, sir, and one question for Mr. Ruckelshaus.

Mr. Hodel, one acid rain proposal that gives this westerner a great deal of trouble is a national tax for the cleanup of powerplants in the Midwest.

On the average, don't westerners already pay more for electricity than people in the Midwest? How much of this cost difference is attributable to the fact that the West has already cleaned up its powerplant emissions?

Mr. HODEL. Senator, I would like to be able to supply for the record the figures on comparative costs of electricity around the country. It is my understanding that, because the powerplants in the West are of a newer order, they have probably more cleanup technology on them than the plants in the rest of the country at the present time.

[The information follows:]

INSERT FOR THE RECORD

The attached table provides a listing of data compiled by the Edison Electric Institute, providing on a state basis, average costs to consumers in 1982 for electricity. These data provide, for the categories of residential, commercial and industrial, the average price for a kilowatt hour (numeric columns 10-12) and the average annual bill (numeric columns 16-18). From this table, we compiled the following tabulation of average residential prices for states in the 31 state area east of and contiguous to the Mississippi River and for the other 17 contiguous states.

Residential Average Price for Electricity
(mills/kwhr) in 1982

Price Range mills/kwhr)	Eastern States	Western States
20-30	0	1
30-40	0	3
40-50	1	2
50-60	11	4
60-70	9	4
70-80	3	3
80-90	5	0
90-100	2	0
Total	31	17

The mean Eastern state cost is about 65 mills while the mean Western state cost is about 55 mills. For the Midwestern states, costs were generally between 55 and 75 mills per kilowatt with a mean value similar to the other Eastern states.

Concerning present and planned installation of sulfur dioxide scrubbers on coal fired power plants, many of these are on western facilities or on low sulfur coal plants. A survey of electric utility units of over 100 MWe having operating or planned scrubbers showed about 90 scrubbers for plants using higher than 1.00% sulfur coal and 80 scrubbers on units burning 1.00% or lower sulfur coal. This survey is compiled for EPRI and used data through September 1983.

There are alternatives to flue gas desulfurization that have been employed by many coal-fired plants to meet SO2 emission limits set by State Implementation Plans or by the 1971 New Source Performance Standards for large boilers. The majority of these would be in midwestern and eastern facilities. Costs for fuel premiums during the past ten years to meet these emission requirements have been about 5 times the expenditure for scrubbing equipment. These costs, too, are reflected in increased rates to customers.

1982 ELECTRICITY CUSTOMER DATA BY STATE

PHYSICAL QUANTITIES--1982

	Sales (million kwh)			Revenues ($millions)			Customers (thousands)		(units)	Average Price (mills/kwh)			Average Consumption kwh/customer			Average Bill ($/customer/yr)		
	Resid	Commer	Indust	Resid	Commer	Indust	Resid	Commer	Indust	Resid	Commer	Indust	Resid	Commer	Indust	Resid	Commer	Indust
Maine	3835	1504	3300	311	113	137	472	57	845	69.32	71.34	44.34	6430	27709	4007667	447	1982	185799
New Hampshire	2551	1135	2370	217	90	154	372	47	1412	85.04	82.82	64.90	6858	24149	1470479	583	2000	95543
Vermont	1760	723	1299	111	44	67	214	24	1103	42.93	67.06	51.58	8213	30125	1170231	319	1033	60771
Massachusetts	12039	12076	8233	1013	977	332	2028	213	10944	84.14	80.90	67.05	5940	56695	752319	501	4587	50441
Rhode Island	1826	1491	1240	137	130	90	341	34	2470	85.90	74.80	72.50	5355	49735	500404	460	3824	36320
Connecticut	8033	7085	5500	717	590	393	1142	107	4794	89.26	83.27	70.33	7034	66213	1145624	628	5514	80577
New York	30484	33768	30729	3019	3459	1642	3749	439	46337	90.38	102.43	53.09	8319	51241	667400	573	5249	35434
New Jersey	13807	17214	15240	1557	1522	1097	2534	310	12643	98.24	88.42	71.94	6204	54132	1205931	610	4786	86756
Pennsylvania	31631	31139	40480	2281	1424	2216	4240	455	30650	72.07	67.46	54.05	7451	66439	1310100	537	3134	72300
Ohio	31197	21091	44353	2094	1362	1040	3913	303	24025	67.12	61.73	41.94	7973	55040	1704244	535	3399	71470
Indiana	17637	10345	25159	1090	514	1137	2025	209	19770	55.91	49.49	45.19	8709	49490	1272617	342	2450	57513
Illinois	29050	25075	31993	2149	1888	1509	4187	393	6535	73.90	72.97	49.47	7073	65840	4896013	523	4804	243171
Michigan	31477	14679	24071	1324	991	1392	3353	321	13965	61.65	67.31	53.39	6401	45729	1866806	395	3087	99678
Wisconsin	14415	9189	13000	913	549	507	1023	176	4295	43.34	61.92	42.99	7987	46003	2233904	501	2903	139015
Minnesota	12855	5490	14609	755	292	474	1539	159	8140	50.73	51.32	45.00	8353	35786	1804656	491	1836	82006
Iowa	9766	5255	8970	423	332	373	1112	147	4991	63.83	63.10	41.58	8770	35748	1797415	348	2250	74742
Missouri	14761	12582	9850	959	470	417	1807	217	10400	57.22	53.59	42.34	8036	57613	947113	504	3088	40076
N. Dakota	2879	1037	1783	140	61	78	258	38	3744	52.76	58.82	43.80	11296	27287	620740	396	1605	28431
S. Dakota	2540	1259	808	145	60	36	268	38	1737	56.91	54.01	40.34	9507	33132	511226	341	1709	20725
Nebraska	7837	4848	3842	329	242	138	677	139	2295	46.75	49.92	35.92	10394	34870	1674874	486	1741	60130
Kansas	7714	7300	4881	499	420	303	931	142	10538	64.69	57.99	46.32	8204	51972	465900	536	3014	29916
Delaware	1723	1326	2233	155	104	128	225	28	443	87.96	79.94	57.32	7430	66300	3360026	607	5300	193062
Maryland and DC	12482	11340	16004	916	792	756	1577	165	4850	47.94	69.72	47.23	8549	68840	3294432	501	4800	155404
Virginia	19900	12390	12326	1276	732	553	1882	187	4249	64.12	59.04	44.86	10576	66299	2900910	478	3914	130140
W. Virginia	4450	2987	9314	346	208	346	714	82	9243	53.58	51.19	37.14	9045	47644	1007952	485	2439	37436
N. Carolina	24709	15896	25190	1476	784	971	2229	294	13320	59.26	51.93	38.55	11175	51347	1891141	442	2667	72890
S. Carolina	13568	7756	19497	771	390	719	1141	144	4502	56.86	51.33	36.88	11680	53847	4244325	446	2764	154594
Georgia	21361	12559	28446	1219	721	807	2066	282	15430	57.34	57.46	43.87	10291	62173	1307456	590	3569	57360
Florida	46282	31040	14590	3265	2002	784	4397	500	30083	70.67	64.40	53.84	10500	62096	726902	743	4004	39139
Kentucky	13252	5700	27905	699	300	1021	1317	144	7960	52.75	52.13	36.90	10042	41028	3512179	531	2139	128130
Tennessee	24578	4654	39475	1154	264	1750	1734	189	10104	46.91	56.73	44.31	14104	24626	2101562	466	1397	96664
Alabama	16485	6927	22544	905	444	1003	1444	175	9803	59.75	64.10	44.49	11416	39583	2402136	482	2537	110432
Mississippi	9652	4434	8415	379	285	419	895	114	7219	59.99	64.28	49.79	10704	38895	1165674	647	2500	58041
Arkansas	8400	4324	8019	320	228	335	889	102	15750	41.26	52.73	37.04	9340	42392	561041	505	2235	21270
Louisiana	18166	10819	25140	1071	574	1068	1522	166	16743	58.96	53.05	42.47	11736	65175	1502001	704	3458	63780
Oklahoma	13199	8642	10136	752	442	395	1264	162	14459	54.97	51.15	38.91	10442	53346	702070	593	2728	27320
Texas	61579	44900	70301	4173	2839	3771	5298	741	59075	67.77	63.11	40.16	11623	60713	1325462	708	3831	63835
Montana	3175	2147	4882	114	71	101	323	52	2970	35.91	32.74	20.69	9830	41673	1643771	353	1365	34007
Idaho	5442	3718	6300	176	127	135	372	46	2041	31.19	34.23	21.40	15147	80820	3091399	473	2082	66148
Wyoming	1712	1424	5039	74	58	147	197	37	2194	43.22	40.73	29.17	8690	38486	2296710	376	1568	67081
Colorado	7424	8945	5412	472	311	220	1174	174	3593	61.91	57.13	40.65	6494	51400	967630	402	2937	39325
New Mexico	2745	2903	3470	208	209	196	440	71	5470	75.77	70.06	56.33	3865	42014	612594	444	2944	34522
Arizona	9306	8150	7301	671	540	400	1094	130	6645	72.10	69.62	54.79	8586	62754	1090721	413	4369	60176
Utah	3638	3033	4618	229	172	192	400	47	7199	63.09	56.71	41.63	7563	64532	640367	477	3660	26670
Nevada	3750	1637	4032	209	119	192	320	39	8095	55.61	72.69	43.32	11457	41974	547470	437	3051	23710
Washington	36639	13794	29610	695	378	537	1640	107	6355	26.09	27.40	18.13	16243	73765	4660582	424	2021	84500
Oregon	14509	9479	12062	484	348	333	1047	140	2832	33.10	37.19	27.41	13934	65399	3937085	442	2432	143910
California	51643	54545	46449	3712	4277	3189	8483	1280	30118	71.80	78.41	40.63	5940	45454	1323526	428	3544	90829

Source: EEI 1982 Yearbook Tables 41A, 30A&B, 53A, & 39A

Senator **Hecht**. Thank you.

Mr. Ruckelshaus, how do the overall cost projections of Senator Mitchell's acid rain control legislation compare with the implementation cost of other major environmental statutes such as the Clean Air Act itself, or the Clean Water Act?

Mr. **Ruckelshaus**. Well, we have spent, and continue to spend——

The **Chairman**. Could I interrupt just a moment, please?

Mr. **Ruckelshaus**. Yes.

The **Chairman**. Secretary Hodel has asked permission to leave 10 minutes ago, or 12 minutes ago.

Does any member object to excusing Secretary Hodel? Secretary Mares will remain.

Senator **Ford**. No.

Senator **Evans**. No.

Senator **Hecht**. No.

The **Chairman**. Secretary Hodel, thank you very much.

Mr. **Hodel**. Thank you very much, Mr. Chairman.

The **Chairman**. Excuse me for interrupting.

Senator **Hecht**. Fine, fine.

The **Chairman**. Mr. Ruckelshaus, please continue.

Mr. **Ruckelshaus**. Senator, the country has spent billions of dollars over the last decade and a half in response to many statutes enacted by Congress to improve the environment. We have detailed those costs over the last several years, both as they relate to hazardous waste, water pollution, air pollution. They are substantial, in the tens of billions of dollars per year.

I would be glad to submit for the record what those costs are and then compare them to the cost associated with the enactment of any of the bills currently pending before Congress.

Senator **Hecht**. Thank you very much.

No further questions.

The **Chairman**. Thank you, Senator Hecht.

Mr. Hodel had in his testimony some cost estimates.

Mr. Mares, the Secretary's testimony was that the burden to reduce emission and associated capital costs would fall on the customers of a relatively small number of utility companies. Ten companies will shoulder about 45 percent of the emission reduction burden.

Mr. Ruckleshaus, do you agree with that statement?

Mr. **Ruckelshaus**. Mr. Chairman, I haven't seen the companies that they suggest there, but I have no reason to doubt it.

The **Chairman**. Would you submit for the record a response as to whether you agree or whether you have a differing background of information?

Mr. **Ruckelshaus**. Our staffs have reviewed individual testimonies. I'm sure that any factual statement in there is consistent with what we believe.

The **Chairman**. Also regarding the cost impact statement: electricity cost impacts have been estimated to range as high as $115 annually per household on some utility systems.

His statement says: In eight States, residential electricity costs are estimated to increase by 10 percent or more, with Missouri and Indiana experiencing increases in excess of 20 percent.

Footnote references to that statement are Temple, Barker, and Sloane.

Mr. Mares, what is that footnote?

Mr. **Mares**. That is a report that was prepared by the firm of Temple, Barker, and Sloane, as described here, and specifically H.R. 3400. We used it as typical of the implication of the massive roll-back proposed legislation.

The **Chairman**. I would also note that the next sentence: Industrial rates would be proportionately impacted. And in the following sentence: for example, the TBS analysis projects that industrial rates in 11 States will go up by more than 10 percent, with four States, Missouri, Indiana, Kentucky, and Ohio experiencing increases in excess of 20 percent.

I note that in particular, because if we have other information that those are exaggerated or inaccurate estimates, I would like to have that reflected for the record.

I would invite any one of the three witnesses before us now to submit for the record an analysis that shows the distribution of costs associated with the rollback provisions for our files or for the record, as the case may be.

[The information follows:]

INSERT FOR THE RECORD

Mr. Mares. The TBS data has been summarized in one table that I have provided. It provides on a state basis the typical annual bill increases that are projected for residential, commercial and industrial customers. For the states of Missouri, Indiana, Kentucky, Ohio, Tennessee, Wisconsin, and West Virginia, the projected rate increase for all three customer categories is 10% or greater. For four other states; Georgia, New Hampshire, Iowa and Illinois; the industrial rate would increase by more than 10%.

In the report summary done for Edison Electric Institute in January 1984, TBS also provided an analysis of how different methods for reporting annual costs could lead to apparently different values, although the net present value cost was constant for all methods. I have also provided this two page summary. Included as one reference point are data from the Office of Technology Assessment (OTA) in which the same present value figure (62 billion dollars) was derived for the compliance cost of H.R. 3400 as was done in the TBS analysis.

A staff memorandum by OTA (July 12, 1983) reports an average state electricity rate increase for residences of about 3.5 percent with a high value of about 10 percent. When the fund is not available to reimburse 90% of capital costs for the "Top-50" plants, the OTA staff report projects 5 states would have a residential rate increases greater than 10%.

CUSTOMER RATE IMPACTS IN ALL 50 STATES

THE LEVELIZED CUSTOMER RATE EFFECTS OF H.R. 3400 CAN BE EXPECTED TO SHOW THESE GENERAL PATTERNS:

- THE AVERAGE RESIDENTIAL BILL COULD INCREASE BY OVER $100 PER YEAR IN 2 STATES, $50 IN 8 STATES, AND $20 OR MORE IN 25 STATES.

- RATES IN SOME STATES COULD INCREASE OVER ACTUAL 1982 LEVELS BY AS MUCH AS 22 PERCENT FOR RESIDENTIAL CUSTOMERS, 24 PERCENT FOR COMMERCIAL CUSTOMERS, AND 29 PERCENT FOR INDUSTRIAL CUSTOMERS.

		TYPICAL ANNUAL BILL INCREASES					
	AVERAGE PRICE EFFECT (MILLS/kWh)	RESIDENTIAL ($/YEAR)	RESIDENTIAL (% OVER ACTUAL 1982 RATES)	COMMERCIAL ($/YEAR)	COMMERCIAL (% OVER ACTUAL 1982 RATES)	INDUSTRIAL ($/YEAR)	INDUSTRIAL (% OVER ACTUAL 1982 RATES)
MISSOURI	12.4	$109	22%	$713	23%	$11,714	29%
INDIANA	11.8	115	21	585	24	15,046	26
KENTUCKY	8.9	89	17	363	17	31,081	24
OHIO	10.7	86	16	592	17	18,310	26
TENNESSEE	6.6	94	14	163	12	14,398	15
WISCONSIN	7.4	59	12	347	12	23,931	17
W. VIRGINIA	5.5	49	10	260	11	5,510	15
GEORGIA	5.3	55	9	330	9	6,941	12
NEW HAMPSHIRE	7.8	53	9	188	9	11,471	12
IOWA	5.3	47	8	189	8	9,526	13
ILLINOIS	5.9	42	8	308	8	28,886	12
PENNSYLVANIA	5.1	30	7	237	8	6,714	9
MICHIGAN	4.1	26	7	185	6	7,561	8
ALABAMA	3.7	42	6	146	6	9,161	8
KANSAS	4.0	33	6	207	7	2,577	9
MARYLAND	3.9	33	6	269	6	12,048	8
MISSISSIPPI	3.4	37	6	132	5	3,963	7
S. CAROLINA	2.7	32	5	145	5	11,465	7
WASHINGTON	1.2	20	5	91	5	5,761	7
FLORIDA	2.9	30	4	180	4	2,105	5
VIRGINIA	2.6	27	4	172	4	7,542	6
MINNESOTA	2.3	19	4	82	4	4,151	5
S. DAKOTA	2.1	20	4	70	4	1,072	5

(CONTINUED)

CUSTOMER RATE IMPACTS ALL 50 STATES (CONTINUED)

		TYPICAL ANNUAL BILL INCREASES					
	AVERAGE PRICE EFFECT	RESIDENTIAL		COMMERCIAL		INDUSTRIAL	
	(MILLS/kWh)	($/YEAR)	(% OVER ACTUAL 1982 RATES)	($/YEAR)	(% OVER ACTUAL 1982 RATES)	($/YEAR)	(% OVER ACTUAL 1982 RATES)
RHODE ISLAND	3.1	17	4	154	4	1,551	4
MASSACHUSETTS	3.0	18	4	170	4	2,257	4
IDAHO	1.1	16	3	65	3	3,309	5
NEW JERSEY	3.3	20	3	179	4	3,980	5
DELAWARE	3.0	23	3	201	4	10,193	5
N. CAROLINA	2.0	22	3	101	4	3,723	5
MONTANA	1.2	11	3	48	4	1,910	6
N. DAKOTA	1.7	19	3	43	3	1,032	4
WYOMING	1.3	11	3	50	3	3,009	4
OREGON	1.0	14	3	63	3	5,756	4
LOUISIANA	1.6	19	3	104	3	2,403	4
NEW YORK	2.6	14	3	133	3	1,735	5
VERMONT	1.3	11	2	39	2	1,532	3
NEBRASKA	0.9	10	2	32	2	1,555	3
NEVADA	1.1	12	2	45	1	586	2
OKLAHOMA	1.1	11	2	37	2	752	3
COLORADO	1.1	7	2	54	2	1,023	3
UTAH	1.1	8	2	69	2	606	3
TEXAS	1.1	13	2	68	2	1,409	2
ARIZONA	1.1	9	1	67	2	1,176	2
CALIFORNIA	1.0	6	1	47	1	1,372	2
NEW MEXICO	1.1	6	1	45	2	656	2
ARKANSAS	0.9	8	1	37	2	485	2
MAINE	0.8	5	1	22	1	3,208	2
CONNECTICUT	0.7	5	1	46	1	816	1

Notes: Price effects are computed on a levelized basis, over 24 years. Percentage increases are the increases over actual customer rates in 1982, the most recent year for which data are available.

Individual utilities within states could experience significantly higher or lower bill effects.

Source: Based on 1982 average price and consumption by customer class from EEI 1982 Statistical Yearbook.

COMPARATIVE METHODS OF REPORTING ANNUAL COMPLIANCE COSTS

MANY ANALYSES ARE IN REASONABLY CLOSE AGREEMENT WHEN ESTIMATING TOTAL COMPLIANCE COSTS OF THIS BILL, YET APPEAR TO DIFFER SIGNIFICANTLY WHEN REPORTING ANNUAL COSTS BECAUSE THEY USE DIFFERENT METHODS FOR REPORTING THE ANNUAL FIGURES.

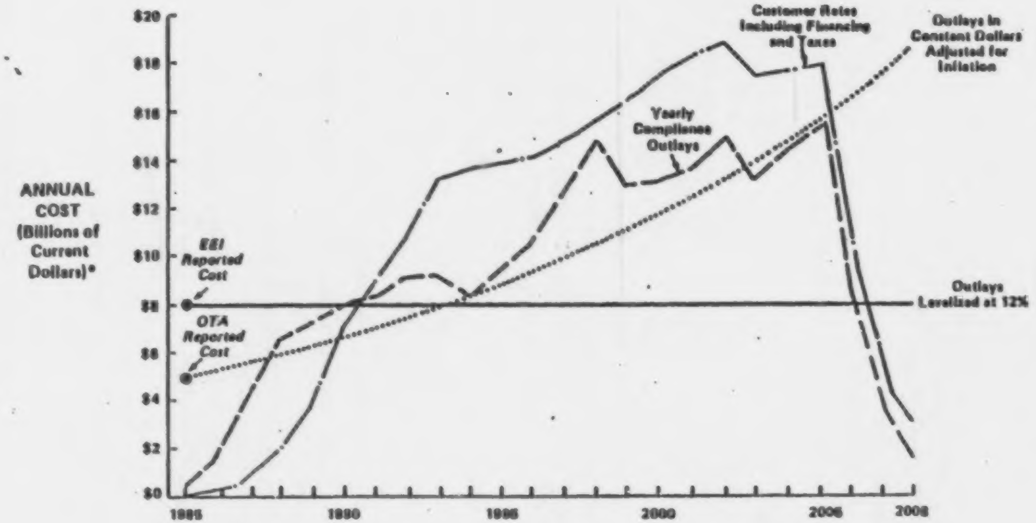
THE CHART ABOVE SHOWS OUR ESTIMATES USING FOUR DIFFERENT METHODS OF REPORTING ANNUAL COSTS:

- ALL FOUR METHODS HAVE THE SAME NET PRESENT VALUE OF $62 BILLION.
- THE "YEARLY COMPLIANCE OUTLAYS" CURVE IS THE SAME AS THAT SHOWN ON PAGE 5. IT REFLECTS ACTUAL CASH OUTLAYS AND VARIES FROM YEAR TO YEAR, FROM $6 BILLION IN 1988 TO OVER $15 BILLION IN THE YEARS 1997-2005.
- THE "CUSTOMER RATES" CURVE IS SIMILAR TO THE OUTLAYS CURVE, DIFFERING ONLY BECAUSE OF TAX AND FINANCING EFFECTS AND THE TIMING OF PASSING THOSE COSTS ON TO CUSTOMERS. THESE AMOUNTS RANGE FROM $2 BILLION IN 1988 TO $18 BILLION BY 2002.
- THE "LEVELIZED" LINE, THE COST CITED IN OUR EARLIER REPORT, IS $7.9 BILLION. LIKE A MORTGAGE PAYMENT, IT IS THE LEVEL AMOUNT THAT WOULD COVER COSTS OVER THE 24-YEAR PERIOD. IT IS ALSO APPROXIMATELY WHAT THE ACTUAL OUTLAYS WOULD BE DURING THE FIRST FEW YEARS OF COMPLIANCE, FROM 1990 TO 1994.
- THE "CONSTANT DOLLARS ADJUSTED FOR INFLATION" CURVE STARTS FROM THE SINGLE POINT ESTIMATE AT THE LOWER LEFT AND INCREASES BY THE RATE OF INFLATION EACH YEAR. THE STARTING POINT AT THE LOWER LEFT IS THE ANNUAL COST IN "CONSTANT 1985 DOLLARS," $4.9 BILLION. BECAUSE OF INFLATION THIS VALUE WOULD INCREASE TO OVER $18 BILLION IN 2008. THE COST REPORTED BY THE OFFICE OF TECHNOLOGY ASSESSMENT (OTA) IN JULY 1983 IS A "CONSTANT DOLLAR" FIGURE LIKE THE POINT AT THE LOWER LEFT OF THE CHART, BUT IN 1982 DOLLARS,WHICH ARE EVEN SMALLER.

IF A SINGLE NUMBER IS TO BE CITED AS "THE ANNUAL COST" OF THIS BILL, WE THINK THE LEVELIZED COST NUMBER OF $7.9 BILLION GIVES A MORE REALISTIC PERSPECTIVE ON THE ANNUAL COSTS THAN DOES THE CONSTANT 1985 DOLLAR FIGURE OF $4.9 BILLION.

TOTAL ANNUAL COMPLIANCE COST OF H.R. 3400
FOUR REPORTING METHODS

(ALL HAVE EQUAL NET PRESENT VALUE OF $82 BILLION)



*Inflation at 6 percent.

Note: "Compliance Costs" include expenses for equipment and construction, operating and maintenance, replacement power, and low sulfur fuel premiums, and exclude financing and taxes.

The **Chairman**. Mr. Ruckelshaus, in your testimony before the committee in the other body on March 29, I refer to page 3 of your statement. As I understand the matter, their preliminary conclusion—and that's referring to the National Academy of Sciences—their preliminary conclusion is that continued deposition at the current rate is unlikely to have any additional impact on watersheds where the soil has a high ability to neutralize acid deposition, or in watersheds whose rate of acidification is at equilibrium with the rate of acid deposition.

Would that indicate to us that where we can measure a difference in different watersheds that a less expensive strategy might involve the improvement of the buffering capacity of those lakes or watersheds?

Mr. **Ruckelshaus**. Well, what it really refers to is this dispute that exists—and it isn't so much of a dispute as it is a lack of data, I think, as the scientists would describe it, between what we are seeing as this rapid response effect, or whether we're seeing a cumulative effect of acid deposition.

And this panel which I mentioned a moment ago, has now just completed its report and expects to release it sometime this week. And it doesn't refer to whether you could mitigate the effects of this by liming or other kinds of approaches to lake management. It refers more to whether we have reached an equilibrium, assuming there's no further decline in the pH of the rainfall or further acidity in the rainfall, which indicates one form of approach to it as opposed to whether we're going to see a continuing decline if the rainfall remains where it is.

The **Chairman**. Rather than reference the report and its conclusions, outside of its conclusions if, indeed, there—well, let me ask a preliminary question.

We do see differences in different watersheds, do we not?

Mr. **Ruckelshaus**. That's right.

The **Chairman**. Even adjacent watersheds. One lake may be highly acidified, and other lakes in the same region not.

Mr. **Ruckelshaus**. That's right.

The **Chairman**. Relating to the buffering capacity of the watershed, or perhaps other factors of which we know nothing.

Mr. **Ruckelshaus**. That's right.

The **Chairman**. If, or little, perhaps is better than nothing.

If that is the case, and you see one watershed in which the acid deposition, by whatever cause, is beyond the capacity of that particular watershed to buffer the acid effects, would that suggest that a strategy might be followed to identify those particular water courses and add to their buffering capacity, rather than trying to halt deposition in all water courses?

Mr. **Ruckelshaus**. That's exactly one of the strategies which we are currently pursuing, Senator, in the liming lake management program that we have suggested for both this year and next, administered by the Interior Department.

We have said in my previous testimony, both in this body and in the House, that at this point we're not suggesting that as an exclusive strategy, because we don't know really how widespread this is.

The **Chairman**. I'm interested in the current information as compared to historic base, and also with respect to the projections, because while you indicated that the sulfur oxide emissions from automobiles is a very small part of the total, you also indicated that mobile sources are a very high proportion of NO_x emissions.

One of the suppositions—and I use that term, because maybe it isn't borne out by fact, but one of the suppositions at the time the Clean Air Act amendments were passed and we moved toward the strategy of removing lead from gasoline and putting catalysts on automobiles was that, indeed, the catalyst might produce not only sulfates, which in combination with moisture create acid, but that the catalyst would also increase the emissions of NO_x. Now, theoretically, that's not necessarily the result of the catalyst. But a poorly tuned automobile engine would provide a high proportion of unburned hydrocarbons to the catalyst. And the function of the catalyst is to cause the oxidation of those unburned hydrocarbons. That produces high temperatures, and high temperatures are usually associated with increased NO_x formation. Is that not correct?

Mr. **Ruckelshaus**. Yes, in general, that's true, Senator. Again, I want to be careful here that we're not getting out at least beyond my knowledge in terms of exactly how that catalyst works and what pollutants it would control under what set of conditions.

The **Chairman**. Do we have recent studies that indicate whether or not we're seeing increased NO_x emissions from catalyst-equipped automobiles?

Mr. **Ruckelshaus**. I don't know that we do, but if we do I will certainly submit them for the record.

We do have problems with tampering with automobiles that are increasing pollutants in general from the automobile, because the catalyst is being removed.

The **Chairman**. And the catalyst strategy was designed to make it easy for automobile makers to build internal combustion motors that didn't have to burn clean, we'd clean it up afterwards.

Mr. **Ruckelshaus**. That's right.

The **Chairman**. Which may have induced them to build ones that are burning dirtier, in effect, leaving the catalyst to clean it up. And if the catalyst isn't there, or has been tampered with, or has been fouled by lead poisoning, then we might be seeing increased emissions from those automobiles rather than decreased emissions. Is that theoretically correct?

Mr. **Ruckelshaus**. Without agreeing with your characterization that what we were doing was encouraging them to build dirtier burning automobiles, it is true, if you remove the catalyst you are increasing the pollutants we're trying to control.

The **Chairman**. Yes.

I thank you. And if you will submit that for the record.

Mr. **Ruckelshaus**. Yes.

[Subsequent to the hearing the EPA submitted the following information:]

UNITED STATES ENVIRONMENTAL PROTECTION
WASHINGTON, D.C. 20460

OFFICE OF
EXTERNAL AFFAIRS

AUG 15 1984

The Honorable Wendell H. Ford
Committee on Energy and Natural Resources
Senate Dirksen Building, Room 360
United States Senate

Dear Senator Ford:

On April 30, 1984, the Committee on Energy and Natural Resources held a hearing on the implementation of the Acid Precipitation Act of 1980. At that hearing, Administrator Ruckelshaus was asked to provide certain information for the record. The requested information is enclosed.

Please accept our apology for any inconvenience that may have been caused by the length of time it has taken the Agency to respond.

Sincerely,

Steadman M. Overman

Steadman M. Overman
Director
Office of Legislative Analysis

Page 78. Senator Evans: Can you share with us, or do you have set forth in any more specific fashion the sort of track that you would follow: (with respect to determining the affect of acid rain on forests).

We are currently in the process of reviewing and adjusting the acid rain research effort as a result of our growing understanding of this problem. We are doing this review in conjunction with the development of EPA's FY'86 budget request and our FY'85 program plans. This is a complicated process, for it involves coordinating our research efforts with those of all the agencies which make up the National Acid Precipitation Assessment Program (NAPAP). When this process is completed (some time in the winter) we will be in a much better position to provide the kind of research overview requested and will be glad to provide to the Committee as specific and timely a response as is possible.

Page 85. Senator Ford: What would be the effect of taking the 1973, which was the peak emission year, as the base year in Senator Mitchell's legislation and reducing the SO_2 emission level to that of the level proposed in his legislation?

If 1973 were to become the base year in Senator Mitchell's legislation fewer aditional reductions of SO_2 would be required. Instead of producing an additional ten million tons of emission reductions the bill would result in roughly a 7 million ton rollback (compared to 1980 levels).

It would be difficult to apply the Mitchell bill formula to the 1973 base year since prior to 1974 plant-by-plant emission data was not collected. However, if the data could be assembled, a 1973 base year would focus more of the required reductions on the heavier emitting states. On the other hand, those states have already achieved significant SO_2 reductions over the last decade. The net impact of these countervailing factors is uncertain.

Page 88 & 89, Senator Ford: Well, does EPA have limits on these sulfur oxide emissions? Senator Ford: Well, do you have a comparison of the sulfur oxides emitted by cars to the sulfur oxide emitted by stationary sources?

Sulfur emissions from highway vehicles are only 1.5 percent of the total sulfur emissions in the eastern United States. For oxides of nitrogen (NO_x), highway vehicles represent about 38 percent of the total emissions for this same area. Mobile Source NO_x emissions have been decreasing due to controls on passenger cars. NO_x emissions from heavy-duty vehicles are expected to increase in the future due to the growth in miles traveled and the greater use of diesel engines which are currently not controlled for NO_x. However, EPA will soon propose more stringent NO_x standards applicable to heavy-duty engines and light-duty trucks.

Page 92. Senator Hecht: How do the overall cost projections of Senator Mitchell's acid rain control legislation compare with the implementation cost of other major environmental statutes such as the Clean Air Act itself, or the Clean Water Act?

There are always difficulties associated with comparing results from different economic analyses because of differences in the methods used in calculating and expressing results. This is certainly true in trying to compare past expenditures for pollution abatement programs as derived from the cost of clean air and clean water reports, and the analysis which we have attempted to adjust the figures so that they are most comparable to each other.

The following display shows past and projected expenditures associated with the Clean Air and Clean Water Acts adjusted to 1982 dollars in billions:

	1970-1981	1982-1990
Clean Air Act Total		
Stationary Source	169.4	247.9
Mobile Source	91.6	172.0
Clean Water Act Total	141.2	264.5
Government Sector	102.3	188.2
Industry Sector	38.9	76.3
Total Federal Air & Water Act Costs	310.6	512.3

Two Congressional proposals S. 3041 and H.R. 3400 have been analyzed by ICF Inc., an independent consulting firm, under contract by EPA. Their analysis of these bills focused on calculating the present net value of their costs. These were calculated for S. 3041 to be \$36.3 billion through the year 2030 and for H.R. 3400 to be \$33.4 billion through the year 2004. Since both of these numbers are present net value calculations, they are not directly comparable to the clean air and clean water costs previously displayed. However, using the ICF report as a basis for estimating the non-discounted cumulative costs through the year 2000, we calculate a cost for S. 3041 of \$28.1 billion, and H.R. 3400 of \$39.9 billion. It should be noted that a substantial share of the 1970 - 1990 cost of clean air and clean water will be born by the electric utility industry. It is therefore somewhat misleading to compare the costs of acid rain control to past expenditures which include SO_2 emission controls.

Page 94. Senator Hecht: Secretary Mares testimony was that the burden to reduce emission and associated capital costs would fall on the customers of a relatively small number of utility companies. Ten companies will shoulder about 45 percent of the emission reduction burden. Do you agree with that statement?

The enclosed report, An Analysis of H.R. 3400, was prepared for EPA by ICF, Inc. That analysis also found that ten companies would be responsible for about forty-five percent of the emission reductions required by the bill. Although the capital costs may initially be borne by those utilities, the bill includes provisions to reimburse them for a significant portion of those expenditures.

The ICF analysis did not attempt to determine rate impacts on individual utility systems. However, their estimates of statewide rate impacts are somewhat smaller than the rate increases projected in the Temple, Barker, Sloane study cited by Secretary Hodel.

Page 99. Chairman: Do we have recent studies that indicate whether or not we're seeing increased NO_x emissions from catalyst-equiped automobiles?

As indicated in the response to Senator Ford, mobile source NO_x emissions have been decreasing due to the use of catalysts on passenger cars and light trucks. However, NO_x emissions from heavy-duty vehicles are expected to increase in the future due to the growth in miles traveled and the greater use of diesel engines which are currently not controlled for NO_x.

ANALYSIS OF THE WAXMAN-SIKORSKI SULFUR DIOXIDE EMISSION REDUCTION BILL (H.R. 3400)

Prepared for
Environmental Protection Agency

By
ICF Incorporated

April 1984

ICF INCORPORATED International Square
1850 K Street, Northwest, Washington, D. C. 20006

Errata Sheet

p. 1-13 Third dot point should read "...For example, Ohio's mining employment is forecasted,to fall relative to 1980 under the Cost-Effective Equivalent..."

PREFACE

This report presents the findings of an analysis performed by ICF Incorporated for the Environmental Protection Agency (EPA). The assumptions, findings, conclusions, and judgments expressed in this report, unless otherwise noted, are those of ICF Incorporated and should not be interpreted as necessarily representing the official policies of EPA or other agencies of the U.S. government.

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INTRODUCTION

OVERVIEW

This report presents and discusses the findings of an analysis of the Waxman/Sikorski Bill (H.R. 3400) performed for the Environmental Protection Agency. The study focused on the cost, emission, and coal market impacts of this bill, which requires sulfur dioxide emission reductions from utility and industrial sources while requiring certain existing utility powerplants to retrofit scrubbers. Further, this bill provides subsidies for the capital costs incurred when retrofitting sulfur dioxide control equipment. The study also examined the cost impacts associated with the utility generation tax imposed to fund these capital subsidies.

The analysis and the findings presented in this report were limited to an assessment of the changes in (1) electric utility and industrial costs and emissions, and (2) regional coal production and coal mining employment. The broader impacts on other sectors of the economy or potential benefits resulting from sulfur dioxide emission reductions were not considered.

APPROACH

ICF's Coal and Electric Utilities Model (CEUM) was used as the primary analytic tool. Base case levels of emissions, costs, fuel consumption, and coal production were identical to those used for previous EPA analyses performed by ICF. Base case specifications are presented in Appendix E.

For each of the emission reduction alternatives, CEUM was used to forecast the associated changes in emissions, costs, generating capacity, fuel consumption, and coal production from the base case. These changes were used to measure the relative impacts of the sulfur dioxide reduction requirements of the Waxman-Sikorski bill.

It was assumed that electric utilities would achieve the emission reductions specified for this analysis in the least-cost manner possible subject to a number of specific provisions and subsidies of the Bill (discussed in Chapter Two). Emission reduction strategies available to utilities included fuel switching, blending, shifts in powerplant utilization, and the retrofitting of scrubbers.

Industrial emissions, costs, and fuel consumption were forecasted using ICF's Industrial Boiler Model (IBM) and Process Heat Model (PHM). Base case forecasts are identical to those used for previous EPA analyses.

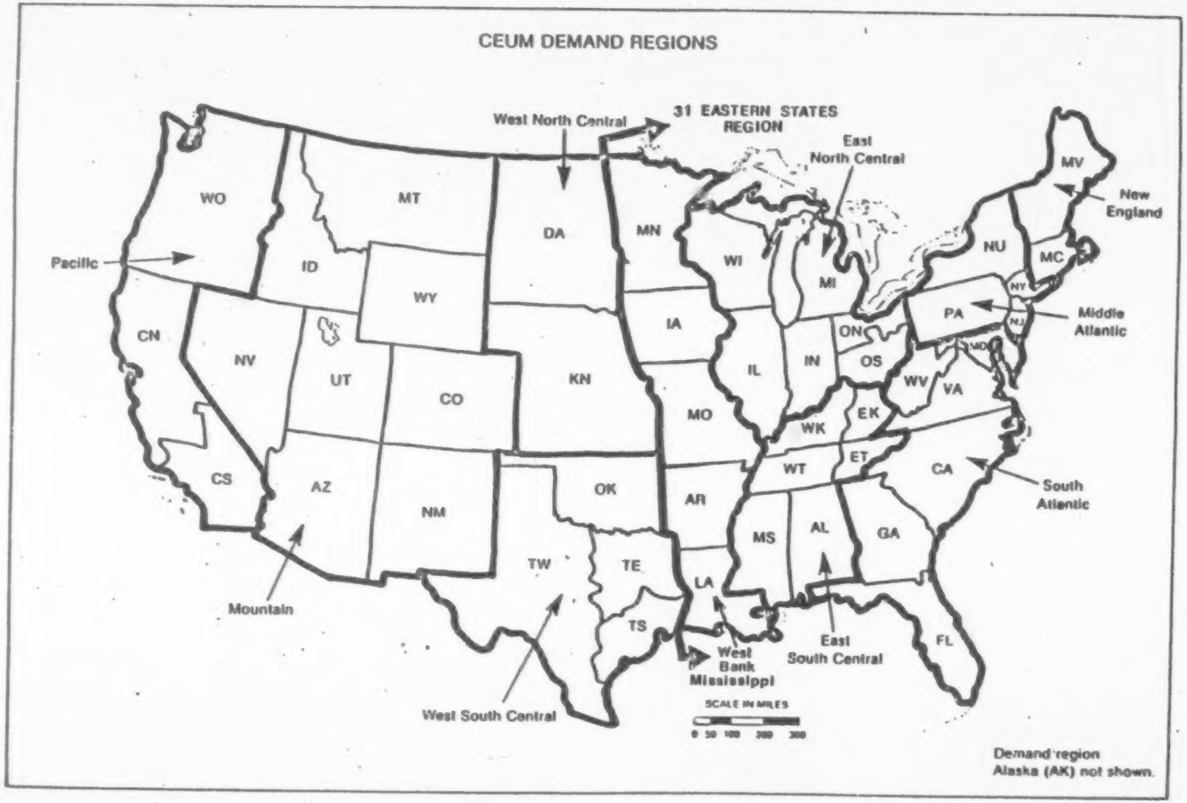
A number of constraints were imposed to reflect real world difficulties in pursuing various emission reduction strategies. These constraints are reviewed in Chapter Four. Market, regulatory, or institutional restrictions and possible transaction and administrative costs related to implementing an emission reduction or subsidy program were not included in this analysis.

MEASURES

Measures used to present the findings in this report are defined and explained below:

- **Geographic Regions**
    - **31 Eastern States** -- 31 states east of or bordering the Mississippi River (see Figure 1 on page 3).
    - **West** -- Other states in the United States (excluding Alaska and Hawaii), consisting of the remaining 17 Western States outside the 31 Eastern States region (see Figure 1 on page 3).
    - **Aggregate CEUM Supply Regions** (see Figure 2 on page 4).
    - **CEUM Demand Regions** (see Figure 1 on page 3).
- **Powerplants by Vintage**
    - **Existing Oil/Gas** -- Oil/gas steam powerplants in operation before December 31, 1980 less all assumed coal reconversions by 1995.
    - **Existing Coal** -- Coal-fired powerplants in operation before December 31, 1980 plus any coal reconversions.
    - **New** -- All powerplants scheduled to begin operation after December 31, 1980.
- **Coal by Sulfur Content**
    - **Low Sulfur** -- less than 1.08 pounds sulfur dioxide per million Btu on a cleaned coal basis.
    - **Low-Medium Sulfur** -- 1.08-1.67 pounds sulfur dioxide per million Btu on a cleaned coal basis.
    - **High-Medium Sulfur** -- 1.67-3.33 pounds sulfur dioxide per million Btu on a cleaned coal basis.
    - **High-Sulfur** -- Greater than 3.33 pounds sulfur dioxide per million Btu on a cleaned coal basis.

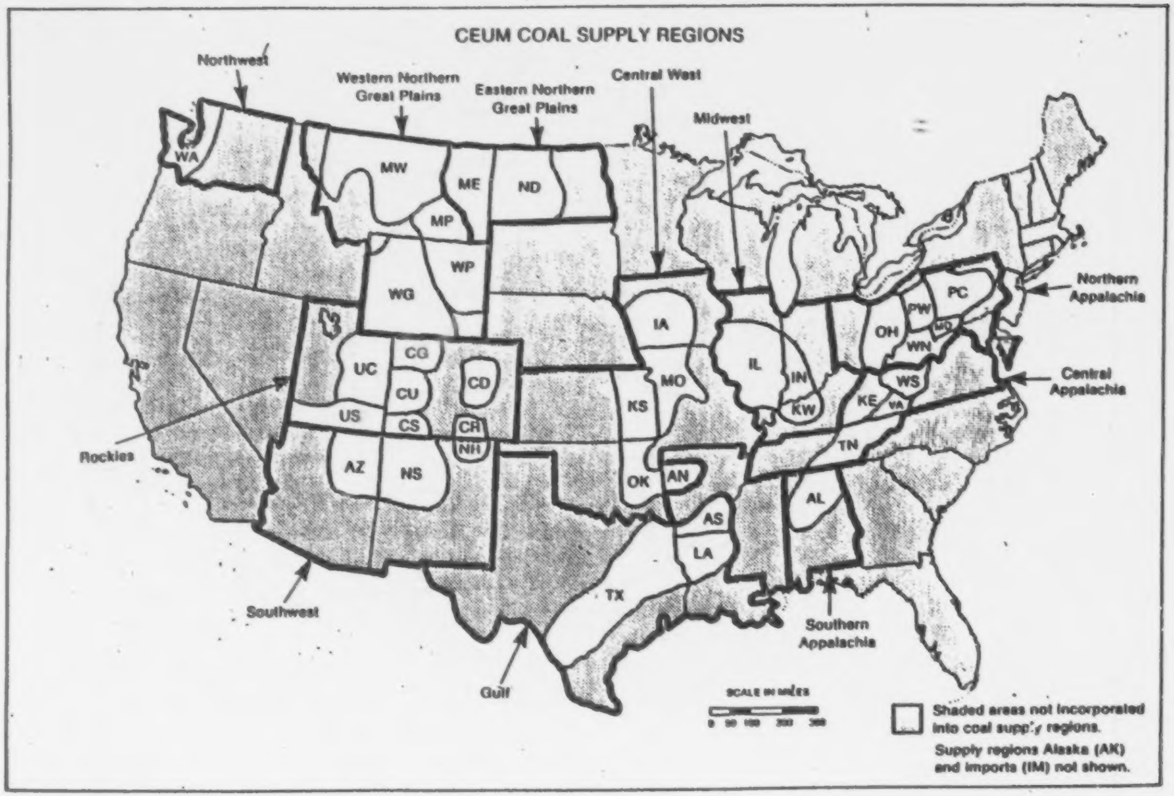
FIGURE 1



CEUM DEMAND REGIONS

31 EASTERN STATES REGION
West North Central
East North Central
New England
Middle Atlantic
South Atlantic
East South Central
West Bank Mississippi
West South Central
Mountain
Pacific
WO
ID
MT
WY
DA
MN
WI
MI
NU
MV
MC
NY
NJ
PA
MD
CN
NV
UT
CO
KN
IA
IL
IN
ON
OS
WV
VA
EK
WK
MO
CS
AZ
NM
OK
AR
WT
ET
CA
MS
AL
GA
TW
TE
TS
LA
FL
SCALE IN MILES
0 50 100 200 300
Demand region
Alaska (AK) not shown.

FIGURE 2



CEUM COAL SUPPLY REGIONS

Northwest
Western Northern Great Plains
Eastern Northern Great Plains
Central West
Midwest
Northern Appalachia
Central Appalachia
Southern Appalachia
Gulf
Southwest
Rockies
WA
MW
ME
ND
MP
WP
WG
UC
CG
CU
CD
US
CS
CR
NH
AZ
NS
IA
MO
KS
OK
AN
AS
LA
TX
IL
IN
KW
OH
PW
PC
MD
WN
WS
KE
VA
TN
AL
SCALE IN MILES
0 50 100 200 300

Shaded areas not incorporated into coal supply regions.

Supply regions Alaska (AK) and imports (IM) not shown.

- **Cumulative Capital Costs** refer to all capital costs incurred for powerplants, equipment, scrubbers or other capital equipment completed after December 31, 1980. Note that these costs will also include any expenditures occurring prior to December 31, 1980 for equipment not finally completed until after this date.

- **Annual Costs** are presented in real terms (mid-1982 dollars)[1] and consist of annualized capital costs (levelized using real capital charge rates), annual fuel costs (based on real annuity prices for coal), and annual operating and maintenance costs.

- **Present Value of Costs** is the present value at the beginning of 1983 (in mid-1982 dollars)[1] of all annualized costs incurred through the year 2005. A 4.26 percent real discount rate was assumed to calculate the present value of utility costs; a 7.9 percent real discount rate was assumed to calculate the present value of industrial costs. (Note in Appendix A which compares the EPA analysis with the OTA and EEI analyses of the Waxman-Sikorski Bill, the present value of costs are at the beginning of 1985 and thus are higher).

- **Levelized Costs** are the present value of costs divided by a real annuity factor. These are presented for the 1985-2005 period and are also in mid-1982 dollars.

- **Costs Per Ton Sulfur Dioxide Removed** are the increases in annualized costs divided by the decrease in annual tons of sulfur dioxide emissions. Costs per ton removed are shown for average values. The marginal costs, which reflect the costs incurred to achieve the last ton of sulfur dioxide emission reduction, were not reported for the scenarios evaluated in this analysis.[2] Had these measures been reported, they would have been significantly higher than the average costs shown.

- **"Annualized" Percent Change in Electricity Rates** is the difference in utility annualized costs in mills per kilowatt hour between the Waxman-Sikorski bill and the base case divided by the 1980 estimated average residential electricity prices for each state in the 31 Eastern States region.

---

[1] Costs in this analysis are presented in mid-1982 dollars to provide comparability with previous acid rain analyses performed for EPA. Using the general CPI as a measure of inflation, the mid-1982 dollars can be restated to early 1984 dollars by multiplying these reported costs by about 1.07.

[2] Specific regulatory provisions in the alternative programs evaluated (i.e., the required retrofit of scrubbers onto the 50 largest sulfur dioxide emitting powerplants) make the measurement of the marginal costs difficult and potentially misleading.

(Note that a more appropriate electricity price for measuring the percent change in electricity rates would be the forecasted price in 1995 in which the cost impacts are measured. In some regions, these prices will be higher in real terms than the 1980 prices, while in others they will be lower. To be consistent with previous analyses performed for EPA and to minimize issues related to forecasting such prices, the 1980 historical prices were selected.)

- **Absolute Change in Electricity Rates** -- is the difference in utility annualized costs in mills per kilowatt hour between the Waxman-Sikorski scenarios and base case levels. This measure provides an estimate of the absolute electricity rate impacts of the Waxman-Sikorski bill on different states.

It should be recognized that the above referenced measures of electricity prices and rates reflect averages of the cost impacts incurred across each of the individual states as shown in Figure 1. As such, the electricity rate impacts and prices for specific utilities within each individual state may be higher or lower than the average measures reported for this analysis. Importantly the approach of states in implementing the specific provisions of the Waxman-Sikorski bill and the manner in which utility regulatory commissions pass any compliance costs through to electricity consumers will be strong determinants in the final electricity rate impacts. These issues have not been addressed in this analysis.

REPORT ORGANIZATION

The following report is divided into four chapters, and four appendices:

- **Chapter One** -- provides and discusses the key findings and compares the emission, costs, production and employment impacts of the Waxman-Sikorski bill with an equivalent emissions reduction case which does not constrain utility options for complying with the required reductions (referred to as the "Cost-Effective Equivalent").

- **Chapter Two** -- reviews the interpretation and specifications for the Waxman-Sikorski bill.

- **Chapter Three** -- discusses (a) the tax required under the Waxman-Sikorski bill to fund the desired subsidies and (b) design issues associated with the capital subsidies for scrubbers.

- **Chapter Four** -- discusses the base case assumptions and the important caveats and uncertainties affecting the findings.
- **Appendix A** -- compares the analysis of the Waxman-Sikorski bill presented in this report with the findings of two other analyses: an analysis by the Office of Technology Assessment (OTA) and analysis by the Edison Electric Institute (EEI).
- **Appendix B** -- provides summary forecasts of the Waxman-Sikorski Bill in 1990.
- **Appendix C** -- provides detailed forecasts of the Waxman-Sikorski Bill and compares these with the Cost-Effective Equivalent case in 1995.
- **Appendix D** -- provides summary forecasts of the Waxman-Sikorski Bill in 2000.
- **Appendix E** -- presents the base case specifications and assumptions.

EXECUTIVE SUMMARY

The Waxman-Sikorski Bill (H.R. 3400) analyzed for EPA and discussed in this report attempts to address a number of the issues raised in other legislative proposals dealing with acid rain:

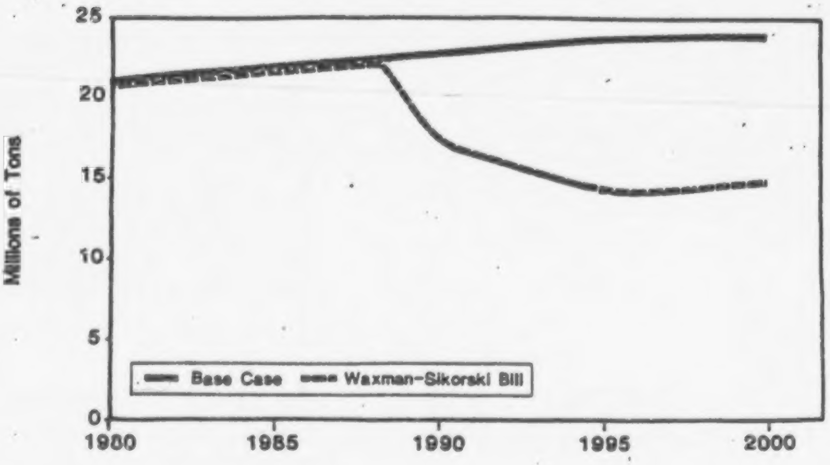
- Requiring reductions relatively early (i.e., by 1990), although the capability of the scrubber and coal industries to support these reductions was not assessed for this analysis.

- Mitigating regional coal production and employment impacts by mandating retrofit scrubbers,

- Spreading or sharing costs more broadly through a tax on all non-nuclear generation by utilities which is used to help subsidize the capital costs of retrofitting scrubbers.

Each of these points are developed in detail in the following report. A few brief summary comments are provided on the following pages.

TOTAL UTILITY AND INDUSTRIAL SULFUR DIOXIDE EMISSIONS
UNITED STATES



By 1990

- Requiring retrofit scrubbers on the fifty largest emitters reduces sulfur dioxide emissions by 5.8 million tons below 1990 levels and 3.4 million tons below 1980 levels.

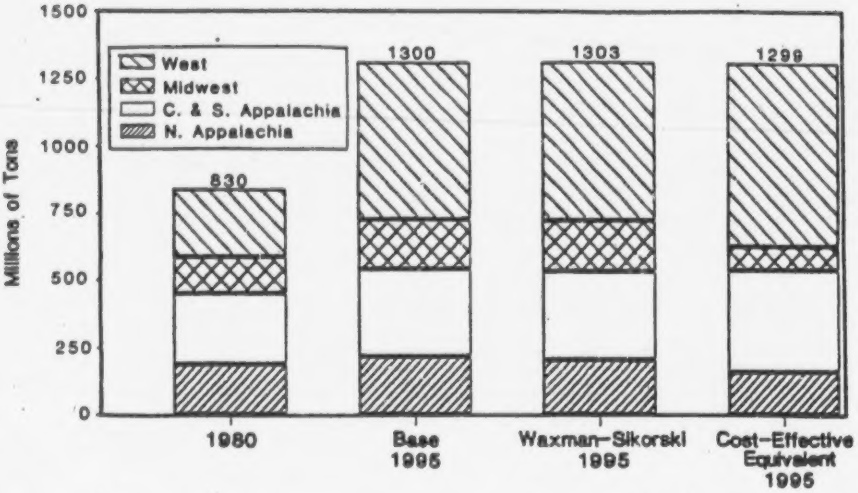
- Almost 60 gigawatts of retrofit scrubbed capacity are required which may be beyond the capabilities of the U.S. scrubber industry without substantial cost increases and potentially poor scrubber performance. Hence, the 1990 emission reductions may not be achievable.

By 1995

- Additional reductions required by 1993 (assumed in 1995 for this analysis) yield a 9.5 million-ton reduction in emissions in 1995. This results in a reduction of 6.2 million tons below 1980 levels.

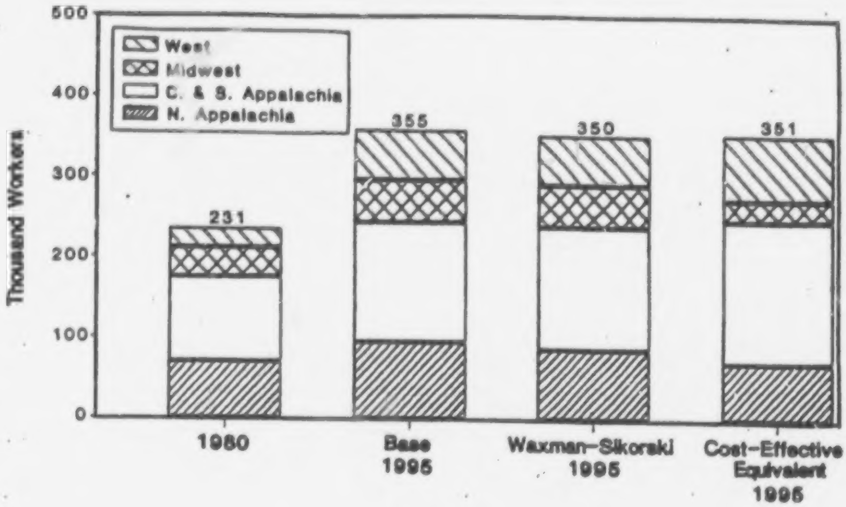
S-3

REGIONAL COAL PRODUCTION



- By mandating scrubbers, the shifts in regional coal production levels and hence, mining employment are minimized when compared to programs which do not mandate scrubbers (i.e., Cost-Effective Equivalent - which requires the same reductions in 1995 as Waxman-Sikorski but permits utilities to pursue the most cost effective reduction opportunities).

REGIONAL COAL MINING EMPLOYMENT



- Acid rain legislative initiatives do not reduce total coal mining employment but initiatives such as the Cost-Effective Equivalent can potentially shift this employment from higher sulfur coal regions to low-sulfur coal regions.

- Because mandated scrubbers reduce shifts in regional coal production, shifts in coal mining jobs from high-sulfur (the Midwest and Northern Appalachia) to low-sulfur (Central Appalachia and the West) coal producing regions are minimized.

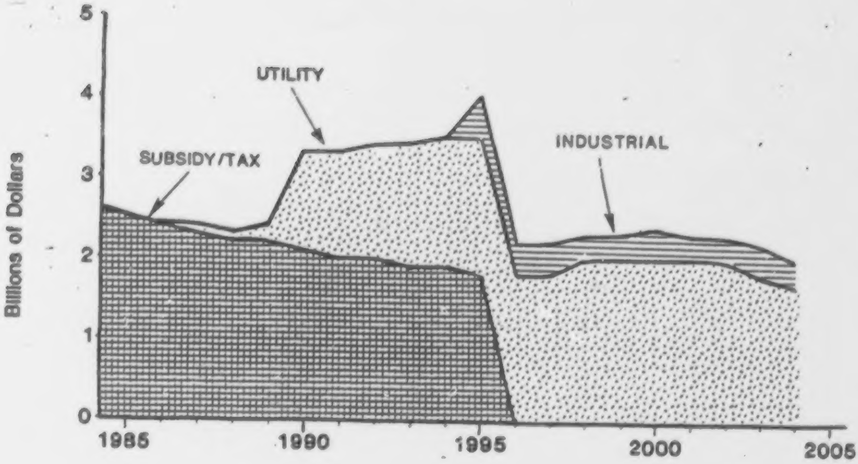
COSTS PER MINING JOBS SAVED - 1995
(in 1982 dollars)

	Waxman-Sikorski	Cost-Effective Equivalent	Difference
Increase in "Levelized" Costs (1985-2005)	2.4	1.4	+1.0
Costs Per Jobs Saved in 1995			
- Gross Basis Relative to 1980	-	-	$52,000
- Gross Basis Relative to 1980 Miners Expected to Employed	-	-	?

- Total mining employment in the U.S. is forecasted to be slightly lower under Waxman-Sikorski (see S-4). However on a regional basis, Waxman-Sikorski is forecasted to preserve mining jobs. The costs per mining job saved depends critically on the measure used:
  - -- Mining jobs saved on a gross basis relative to 1980 refers to any forecasted reduction in jobs in a coal supply region (See Appendix C) below 1980 levels under the Cost-Effective Equivalent (i.e., 19.5 thousand jobs) relative to Waxman-Sikorski (i.e., 0.2 thousand jobs).
  - -- Mining jobs saved on a gross basis relative to 1980 Miners Expected to be Employed takes into account normally expected retirements of existing miners by 1995. As a result, the cost per miner saved would be higher than $52,000. This was not analyzed for the EPA study.
- Measures of jobs saved presented herein include only the coal mining jobs saved. Jobs in related industries and in the local economies will also be saved on a gross basis resulting in lower costs per total jobs saved than noted above. This was not examined for this analysis.
- Measures of mining jobs lost and saved relative to 1980 will be affected significantly by the base case forecasts. See Chapter Four for further discussion.

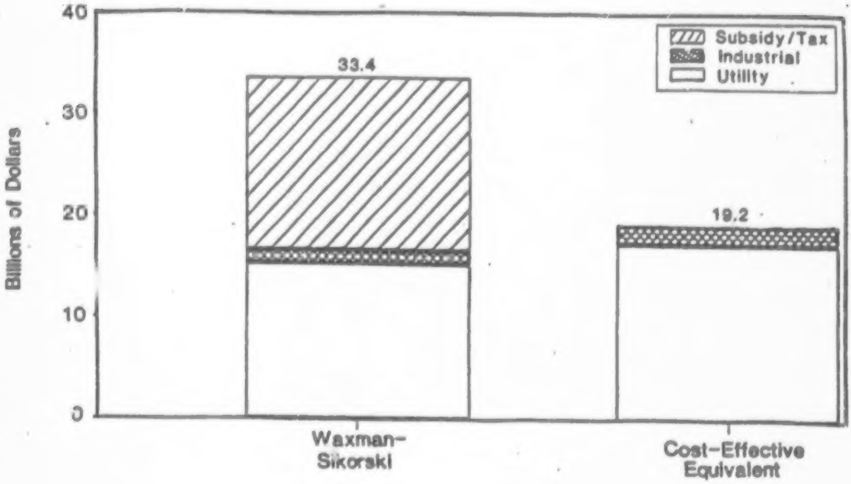
S-6

ANNUALIZED COST IMPACTS OVER TIME
WAXMAN-SIKORSKI BILL
(in 1982 dollars)



- Annualized costs of the Waxman-Sikorski bill reflect:
  - -- The generation tax from 1985 through 1995 to fund the capital subsidies (i.e., Subsidy/Tax Costs),
  - -- The requirement to scrub the 50 highest emitters in 1990 (i.e., Utility Costs), and
  - -- The costs of the entire emission reduction program by 1995 - the 9.5 million ton reduction as well as the costs of scrubbing the 50 highest emitters (i.e., Utility and Industrial Costs).

INCREASE IN PRESENT VALUE OF COSTS
(in 1982 Dollars)



- The present value of annualized costs is forecasted to be higher by almost $15 billion when retrofit scrubbers are mandated and subsidized than when they are not (i.e., the Cost-Effective Equivalent).
- The higher costs result from utilities pursuing less cost-effective strategies for meeting the overall reduction requirements (e.g., scrubbing in lieu of shifting to lower sulfur coals).

PRESENT VALUE OF REGIONAL UTILITY COSTS AND GENERATION TAX

	Percent of Total Present Value Costs		Present Value of Utility and Tax Costs (billions of 1982$)	
	Waxman-Sikorski Bill	Cost-Effective Equivalent	Waxman-Sikorski Bill	Cost-Effective Equivalent
Pennsylvania	7.8%	8.7%	2.5	1.5
West Virginia	6.2%	8.1%	2.0	1.4
Georgia	2.8%	4.6%	0.9	0.8
Florida	3.7%	1.7%	1.2	0.3
Ohio	12.1%	24.3%	3.9	4.2
Michigan	2.5%	1.7%	0.8	0.3
Indiana	6.8%	14.5%	2.2	2.5
Illinois	4.7%	4.0%	1.5	0.7
Wisconsin	3.1%	4.6%	1.0	0.8
Kentucky	4.3%	5.2%	1.4	0.9
Tennessee	5.6%	5.8%	1.8	1.0
Missouri	5.6%	7.5%	1.8	1.3
Total 12-States	65.2%	90.8%	21.0	15.7
Other 19-States	14.3%	4.0%	4.6	0.7
Total 31-Eastern States	79.5%	94.8%	25.6	16.4
Total 17-Western States	20.5%	5.2%	6.6	0.9
Total U.S.	100.0%	100.0%	32.2	17.3

- The tax on utilities for all non-nuclear generation and the capital subsidy for retrofit scrubbers tend to spread the overall cost impacts, in percentage terms, more evenly across the affected states. Western states in particular have a much higher share of total costs, while many Midwestern states have a lower share.

- However, for most states (other than Ohio and Indiana) the Waxman-Sikorski bill is more expensive in absolute terms than a Cost-Effective Equivalent.

CHAPTER ONE

SUMMARY OF FINDINGS

This chapter presents an overview of the major findings of the ICF analysis of the Waxman-Sikorski Bill (H.R. 3400). For comparison purposes, forecasts of an alternative proposal with similar sulfur dioxide emission reduction requirements but without the subsidies and scrubbing requirements (referred to as the "Cost-Effective Equivalent") are provided. The major topics discussed in this chapter are:

- Interpretation of the Waxman-Sikorski Bill and Description of the Cost-Effective Equivalent
- Emission and Cost Impacts
- Coal Production and Employment Impacts
- Regional Emission and Cost Impacts
- Uncertainties in the Interpretation of the Waxman-Sikorski Bill

BASIC INTERPRETATION OF WAXMAN-SIKORSKI BILL AND COST-EFFECTIVE EQUIVALENT EMPLOYED IN THIS ANALYSIS

Waxman-Sikorski

By 1990

- The 50 largest sulfur dioxide emitting powerplants with emission rates above 3.0 pounds sulfur dioxide per million Btu are required to install and operate scrubbers by 1990, removing 70 to 90 percent of the sulfur dioxide from the flue gas.

By 1995

- A targeted reduction of 10 million tons in sulfur dioxide emissions below 1980 levels is required by 1995 (actual bill required 1993). This includes the reductions achieved earlier by the mandated scrubbers. Allowances or credits are permitted for emission increases from greater powerplant utilization, fuel shifts (except at coal-fired plants), and new sources.
- These total reductions are allocated to individual states based on "excess" emissions at utility sources emitting above a 1.2 pound sulfur dioxide per million Btu rate in 1980. No trading of emission reductions was permitted between different states, but trading was permitted among utility and industrial sources within states.

1985-1995

- A subsidy was provided for 90 percent of the capital costs (and related capital charges) associated with any retrofit scrubbers.
- A tax on non-nuclear electricity generation plus electricity imports was specified to fund the scrubber capital subsidies. The tax was set at about 1.4 mills per kilowatt hour (in nominal dollars) and was assumed to begin in 1985 terminating at the end of 1995.

Cost-Effective Equivalent

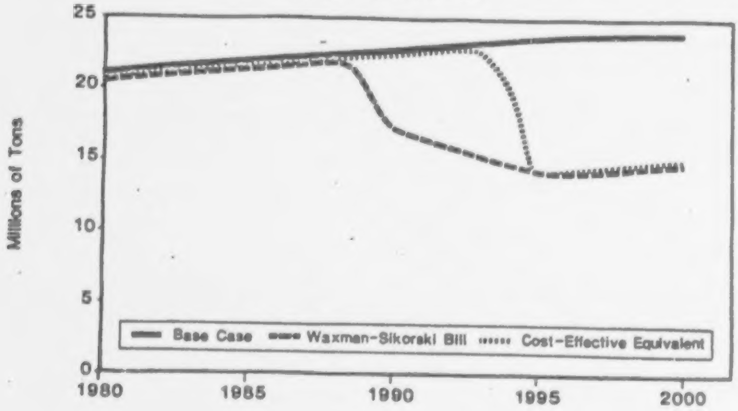
By 1990

- No reductions were assumed or specified

By 1995

- Same targeted level of reductions as in the Waxman-Sikorski bill was required. However, this case did not mandate retrofit scrubbers, did not provide subsidies or specify taxes, and permitted interstate trading of emission reductions.

TOTAL UTILITY AND INDUSTRIAL SULFUR DIOXIDE EMISSIONS-UNITED STATES



By 1990

- Requiring retrofit scrubbers to be installed and operated by 1990 at the largest emitters under the Waxman-Sikorski bill reduces emissions by 5.8 million tons below 1990 levels. Because of growth in emissions, this results in a 3.4 million ton reduction below 1980 levels.

- No reductions are specified under the Cost-Effective Equivalent Case in 1990.

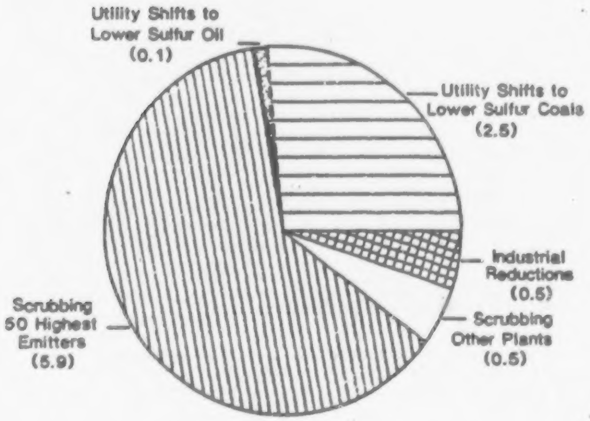
- This study did not assess the scrubber industry's capacity to install scrubbers on the fifty highest emitters. A subsequent ICF study for the Alliance for Clean Energy found that the industry does not have the capacity to do so by 1990 without a substantial cost increase and/or potentially poor scrubber performance. Hence, the 1990 emission reductions required by the Waxman-Sikorski bill may not be achieved. Some industry representatives have indicated that while installing these scrubbers may be difficult, it could be possible.

By 1995

- Waxman-Sikorski's "10-Million Ton Reduction Below 1980 levels from Existing Plants" amounts to a total 9.5 million ton reduction below 1995 levels when all credits and exclusions are taken into account. Because of a forecasted increase in sulfur dioxide emissions between 1980 and 1995, of about 3.3 million tons, this amounts to a 6.2 million ton reduction below 1980 levels.

- Identical reductions were required under the Cost-Effective Equivalent Case.

SULFUR DIOXIDE EMISSION REDUCTION STRATEGIES
WAXMAN-SIKORSKI BILL - 1995
(Millions of Tons)



Total Reductions-9.5 Million Tons

- Most of the 9.5 million tons of sulfur dioxide emission reductions forecasted under the Waxman-Sikorski bill in 1995 are expected to come from scrubbing:

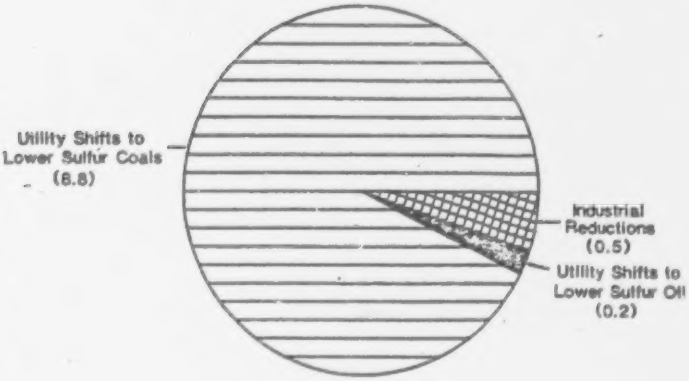
  -- About 5.9 million tons from the 50 highest emitting powerplants being forced to scrub.

  -- An additional 0.5 million tons from other units opting to scrub because it is less costly on a cost-per-ton removed basis (including the subsidy) than reducing emissions through fuel shifts. Note, if the subsidy was excluded, these units would probably not scrub.

  -- The remaining 3.1 million tons through utility shifts to lower sulfur coals, greater utilization of lower emitting coal plants, utility shifts to lower sulfur oils, and industrial reductions through shifts to lower sulfur coals.

SULFUR DIOXIDE EMISSION REDUCTION STRATEGIES COST EFFECTIVE EQUIVALENT - 1995

(Millions of Tons)



Total Reductions-9.5 Million Tons

- Most of the 9.5 million ton reduction under the Cost Effective Equivalent case is forecasted to come through fuel switching or increasing utilization of lower emitting plants:

  -- About 8.8 million tons from coal-fired powerplants switching to lower sulfur coals or increasing utilization of lower emitting powerplants.

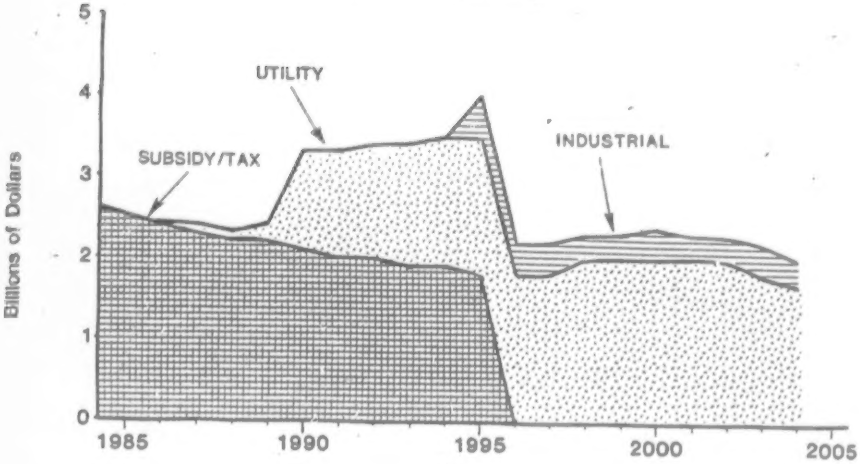
  -- About 0.5 million tons from industrial sources switching to lower sulfur coals.

  -- About 0.2 million tons from oil fired powerplants switching to lower sulfur oils or increasing utilization of lower sulfur oil plants.

  -- Less than 0.1 million tons from retrofitting existing powerplants with scrubbers. Without a 90 percent capital subsidy, scrubbing is considerably more expensive than fuel switching as an emission reduction strategy.

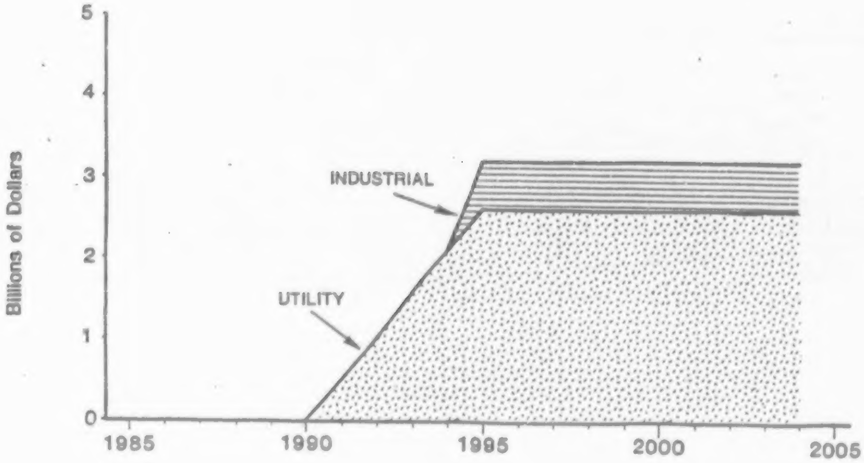
ANNUALIZED COST IMPACTS OVER TIME
WAXMAN-SIKORSKI BILL

(in 1982 dollars)



- Annualized costs are forecasted to be high in the early years (1985-94) of the Waxman-Sikorski program reflecting:
  - -- The generation tax to fund the capital subsidies (i.e., Subsidy/Tax Costs), and
  - -- The requirement to scrub the 50 highest emitters in 1990 (i.e., Utility Costs)
- Annualized costs are forecasted to be highest in 1995 under the Waxman-Sikorski bill reflecting -
  - -- The last year of the generation tax (i.e., Subsidy/Tax Costs), and
  - -- The costs of the entire emission reduction program - the 9.5 million ton reduction as well as the costs of scrubbing the 50 highest emitters (i.e., Utility and Industrial Costs).
- Annualized costs are lower after 1995 because
  - -- The generation tax has been terminated.
- No specific near-term constraints on scrubber capacity were evaluated for this analysis. Other analyses performed recently suggest that such constraints could at a minimum significantly increase the cost impacts in 1990 and potentially render infeasible compliance with the requirement to scrub the 50 highest emitters by 1990.

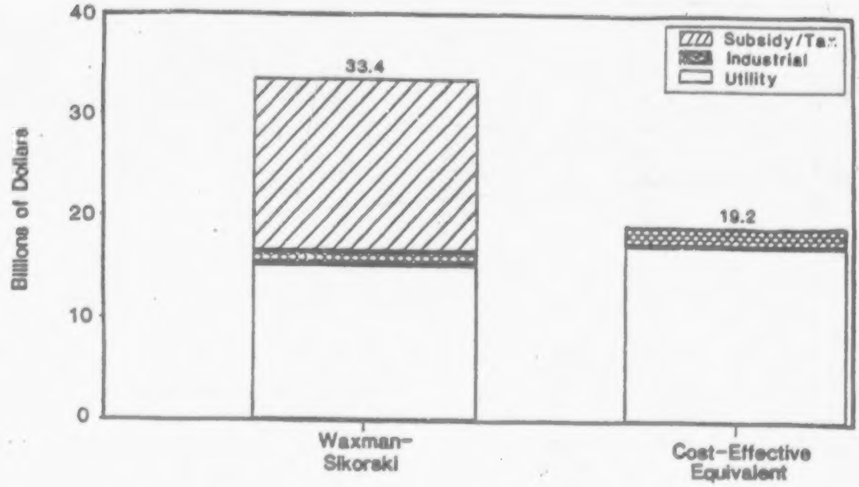
ANNUALIZED COST IMPACTS OVER TIME
COST-EFFECTIVE EQUIVALENT
(in 1982 Dollars)



- A comparison of the forecasted annual costs over time of the Cost-Effective Equivalent with the Waxman-Sikorski bill indicates that the Waxman-Sikorski bill is somewhat cheaper in the later forecast years (1996-2005) but significantly more expensive in the earlier years (1985-1995). Compliance costs in the later forecast years are lowered significantly through the capital subsidies for retrofit scrubbers, but costs are much higher in the early years because of the generation tax to fund the subsidy.

- Costs are also higher in the early years (1985-1995) under the Waxman-Sikorski bill because of the requirement to install retrofit scrubbers at the 50 highest emitting utility powerplants by 1990. No emission reductions were assumed to be required under the Cost-Effective Equivalent until 1995.

INCREASE IN PRESENT VALUE OF COSTS
(in 1982 Dollars)



- The present value of annualized costs is forecasted to be higher under the Waxman-Sikorski bill than the Cost-Effective Equivalent by almost $15 billion. This is because the Waxman-Sikorski bill:

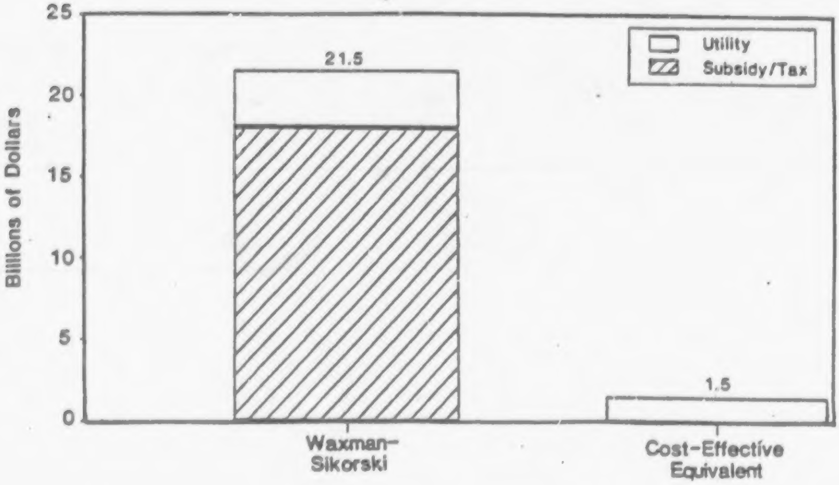
  -- requires the 50 highest emitters to scrub and encourages additional scrubbing through a 90 percent capital subsidy. Since scrubbing is generally a more costly reduction strategy (on a cost-per-ton removed basis) than shifting to lower sulfur coals, forcing or encouraging the installation of scrubbers results in higher total costs.

  -- requires reductions through scrubbing by 1990. No reductions were assumed under the Cost-Effective Equivalent until 1995.

  -- does not permit the trading of emission reductions between states (i.e., interstate trading). Interstate trading was permitted under the Cost-Effective Equivalent.

- More than half the total present value costs of the Waxman-Sikorski bill are capital subsidy costs. This is because most of the costs of reduction under the bill are associated with scrubbing and most of the scrubbing costs are capital costs.

INCREASE IN CUMULATIVE CAPITAL COSTS - 1995
(in 1982 Dollars)



- By 1995, total capital expenditures are forecasted to be significantly higher under the Waxman-Sikorski bill than under the Cost-Effective Equivalent (about $20 billion more). This reflects the much greater number of retrofit scrubbers under the Waxman-Sikorski bill (67.5 Gw versus 2.5 Gw).

- All the cost estimates presented in this analysis assume that scrubbers can be retrofitted by 1990 as required under the Waxman-Sikorski bill. In fact, another analysis conducted by ICF[1] indicates that the capacity to retrofit scrubbers in the near term is limited. As such, either the requirements of the Waxman-Sikorski bill may have to be delayed to allow time for the scrubbers to be designed and installed, or the costs incurred may be significantly higher, or compliance with the bill may be infeasible.

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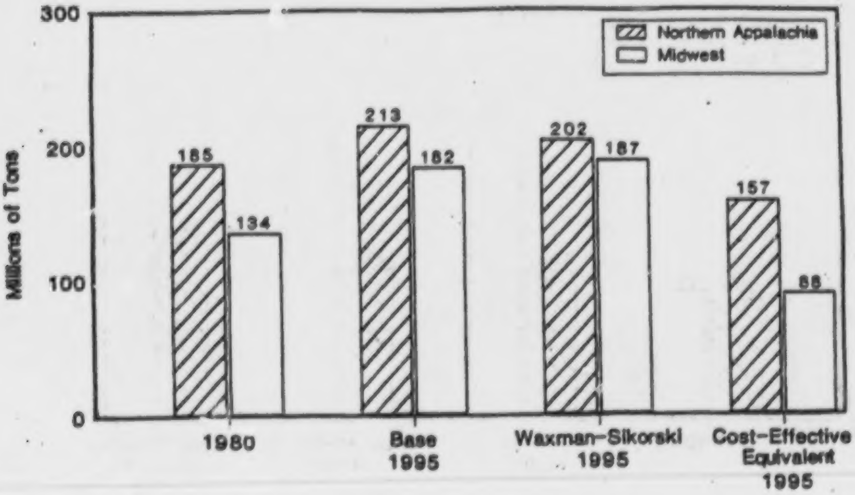
[1] See ICF report prepared for the Alliance for Clean Energy entitled Analysis of Cost Effective Phased-In Reductions of Sulfur Dioxide Emissions February, 1984.

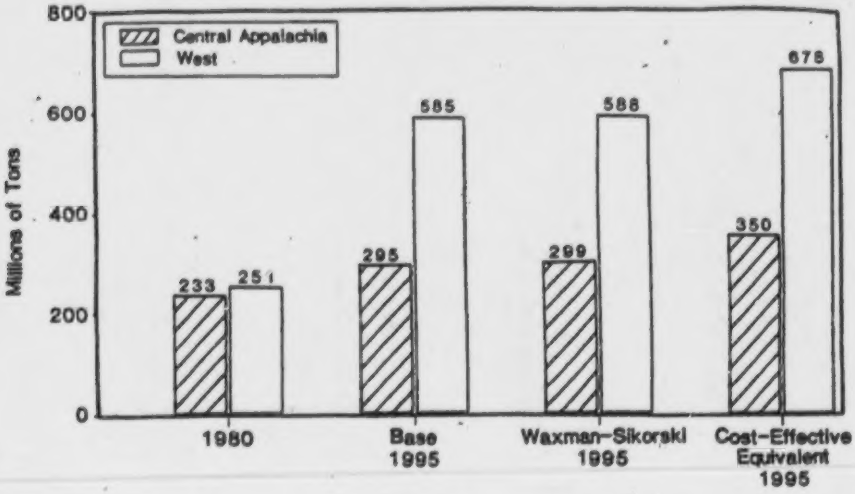
HIGH SULFUR COAL PRODUCTION



- Major high sulfur producing regions in the Midwest and Northern Appalachia are forecasted to maintain production at roughly 1995 base case levels and above 1980 levels under the Waxman-Sikorski bill. This is because the 50 highest emitters are forced to scrub and other powerplants are encouraged to scrub through a 90 percent capital subsidy. These powerplants will generally scrub higher sulfur coals, either continuing to consume or shifting to consume high sulfur coals.

- Under the Cost-Effective Equivalent case, production from high-sulfur regions falls, even below 1980 levels. This reflects forecasted shifts in consumption by utilities from high to lower sulfur coals. This compliance strategy is selected most often because it is the most cost effective method of reducing emissions, in the absence of subsidies and regulations mandating retrofit scrubbers.

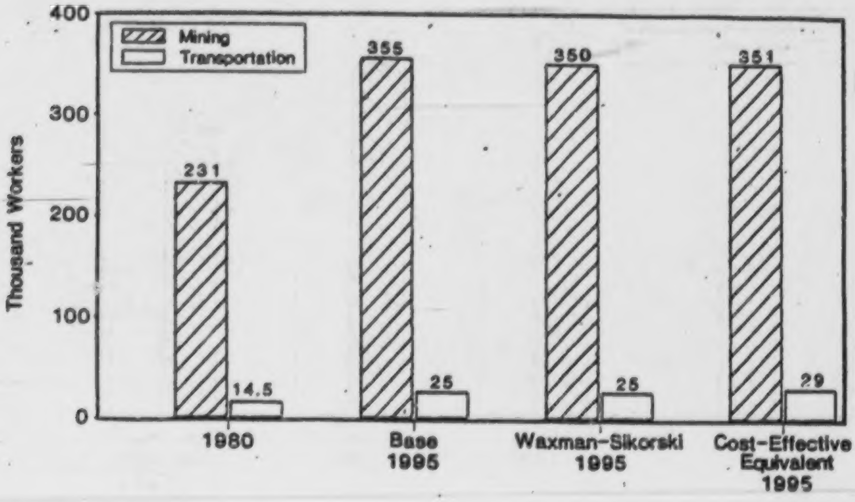
LOW SULFUR COAL PRODUCTION



- Low sulfur coal producing regions in Central Appalachia and the West are forecasted to show little change in production under the Waxman-Sikorski bill and significant increases under the Cost-Effective Equivalent. This reflects the shifts in utility coal consumption discussed previously.

- Most of the production increases in the West under the Cost-Effective Equivalent are forecasted to be in bituminous coal producing regions of the Rockies and the Southwest rather than subbituminous coal producing areas in the Western Northern Great Plains. This is because most of the emissions reductions are forecasted to occur in the East in boilers designed to burn higher-rank bituminous coals. In this analysis, the ability to burn subbituminous coals in these boilers was not assessed. To the extent this is cost-effective, some of the western increases could come from the Western Northern Great Plains.

TOTAL COAL MINING AND TRANSPORTATION EMPLOYMENT

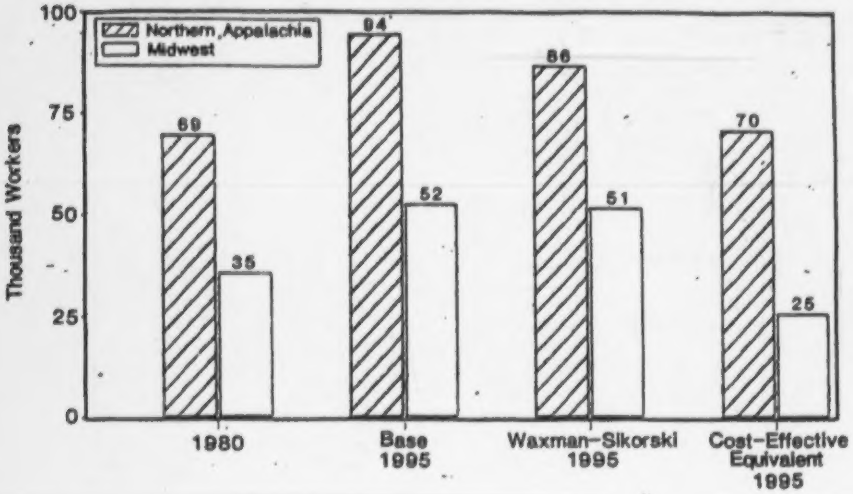


- Coal mining employment in the base case is forecasted to grow by 1995 in all aggregate supply regions reflecting the forecasted growth in coal production. However, coal-mining employment levels do not rise in direct proportion to changes in coal production. This is because average productivity in a region will change over time as surface reserves are depleted, more expensive-to-mine reserves are developed, and the mix of the different types of coals mined changes.

- Aggregate coal mining employment in the U.S. is not forecasted to be significantly different under the Waxman-Sikorski bill and the Cost-Effective Equivalent. However, regional employment is forecasted to shift significantly under the Cost-Effective Equivalent with high sulfur producing regions losing relative to the 1995 base case employment levels and low sulfur producing areas gaining.

- Transportation employment is forecasted to be about the same under the Waxman-Sikorski bill as the base case in 1995. However, the Cost-Effective Equivalent is expected to increase transportation employment above base case levels because of the shifts by utilities to more distant lower sulfur coals.

HIGH-SULFUR COAL MINING EMPLOYMENT



- Coal mining employment in the base case is forecasted to grow even in high-sulfur producing regions. Consistent with modest shifts in regional coal production under the Waxman-Sikorski bill relative to base case levels, regional coal mining employment is not forecasted to change significantly. Under the Cost-Effective Equivalent, coal mining employment is forecasted to decrease significantly in Northern Appalachia and the Midwest.

- Coal mining employment in the Midwest is forecasted to decline below 1980 levels consistent with the coal production losses forecast for this region under the Cost-Effective Equivalent. Note however, that the extent of forced mine closings and/or layoffs will not be proportional to the forecasted decline in mining employment. This is because between 1980 and 1995 some mines will have depleted their reserves and some existing miners will have retired.

- The shifts in coal mining employment by aggregate supply region mask significant changes forecasted to occur on a more local level. For example, Ohio's mining employment is forecasted to fall relative to 1980 under the ~~Waxman-Sikorski bill~~ Cost-Effective Equivalent (see Appendix C) although the aggregate employment levels in Northern Appalachia are expected to remain about constant.

REGIONAL UTILITY EMISSION REDUCTIONS WAXMAN-SIKORSKI BILL AND COST EFFECTIVE EQUIVALENT -- 1995

	SO_2 Emission Reductions			
	Waxman-Sikorski Bill		Cost Effective Equivalent	
	Thousands of Tons	Percent of Total	Thousands of Tons	Percent of Total
Pennsylvania	-546	6%	-176	2%
West Virginia	-593	6%	-469	5%
Georgia	-419	5%	-365	4%
Florida	-285	3%	-406	5%
Ohio	-1,742	19%	-1,447	16%
Michigan	-123	1%	-219	2%
Indiana	-1,237	14%	-1,189	13%
Illinois	-535	6%	-561	6%
Wisconsin	-419	5%	-469	5%
Kentucky	-447	5%	-372	4%
Tennessee	-605	7%	-629	7%
Missouri	-960	11%	-941	11%
Total 12-States	-7,911	88%	-7,243	80%
Other 19-States	-801	9%	-1,409	16%
Total 31-Eastern States	-8,712	97%	-8,652	96%
Total 17-Western States	-292	3%	-352	4%
Total U.S.	-9,004	100%	-9,004	100%

- The Waxman-Sikorski bill concentrates about 88 percent of the forecasted utility sulfur dioxide emission reductions in 1995 within 12 states (generally located in the Midwest). This reflects the method used to allocate the 10 million ton reduction required under the bill; the 1.2 pound-excess-emissions-allocation scheme. Most of the utility powerplants in the 12 aforementioned states consumed higher sulfur coals or fuels in 1980 than the rest of the U.S. As such, about 86 percent of the excess emissions were estimated to come from these states.

- Less emission reductions are concentrated within the 12-States in 1995 under the Cost-Effective Equivalent. This is because the Cost-Effective Equivalent permits interstate trading to occur. States with more costly reductions are permitted to trade emission reductions with states having less costly opportunities to reduce emissions. A number of states outside the 12-State area have more cost-effective reduction opportunities than those within this area.

REGIONAL UTILITY COSTS AND SCRUBBER CAPACITY

	Present Value of Utility Costs and Generation Tax (billions of 1982$)		Retrofit - 1995 Scrubber Capacity	
	Waxman-Sikorski Bill	Cost-Effective Equivalent	Waxman-Sikorski Bill	Cost-Effective Equivalent
Pennsylvania	2.5	1.5	6.7	-
West Virginia	2.0	1.4	5.1	-
Georgia	0.9	0.8	3.6	1.1
Florida	1.2	0.3	2.8	-
Ohio	3.9	4.2	12.5	0.5
Michigan	0.8	0.3	1.4	-
Indiana	2.2	2.5	9.7	-
Illinois	1.5	0.7	5.0	-
Wisconsin	1.0	0.8	1.0	-
Kentucky	1.4	0.9	3.2	0.9
Tennessee	1.8	1.0	8.0	-
Missouri	1.8	1.3	5.3	-
Total 12-States	21.0	15.7	64.3	2.5
Other 19-States	4.6	0.7	2.2	-
Total 31-Eastern States	25.6	16.4	66.5	2.5
Total 17-Western States	6.6	0.9	1.0	-
Total U.S.	32.2	17.3	67.5	2.5

- For a few states (e.g., Ohio and Indiana), the Waxman-Sikorski bill is preferable to the Cost-Effective Equivalent in terms of total costs. These states are generally forecasted to retrofit a large amount of scrubber capacity (and thus have most of their compliance costs subsidized).

- For most other states, the Waxman-Sikorski bill is more expensive than the Cost-Effective Equivalent. Although relatively few of the reductions are forecasted in these regions, the tax imposed on non-nuclear generation by the Waxman-Sikorski bill substantially increases the near-term costs to these states. States other than the 12-States account for about 57 percent of the forecasted non-nuclear generation and thus a comparable portion of the tax payments, yet these states receive virtually none of the subsidies.

REGIONAL DISTRIBUTION OF TAXES AND SUBSIDY PAYMENTS
WAXMAN-SIKORSKI BILL
(in 1982 dollars)

	Present Value of Subsidies		Present Value of Taxes Paid		Present Value of Net Subsidies (Subsidies-Taxes)
	$ billions	% of total	$ billions	% of total	$ billions
Pennsylvania	1.8	11	0.8	5	1.0
West Virginia	1.3	8	0.6	3	0.7
Georgia	0.9	5	0.5	3	0.4
Florida	0.8	5	0.6	3	0.2
Ohio	3.1	18	0.8	5	2.3
Michigan	0.4	2	0.5	3	-0.1
Indiana	2.6	14	0.7	5	1.9
Illinois	1.3	8	0.7	4	0.6
Wisconsin	0.3	2	0.3	2	-
Kentucky	0.9	5	0.7	4	0.2
Tennessee	1.8	11	0.6	3	1.2
Missouri	1.3	8	0.5	3	0.8
Total 12-States	16.5	97	7.3	43	9.2
Other 19-States	0.4	2	3.6	21	-3.2
Total 31-East	16.9	99	10.9	64	6.0
Total 17-West	0.1	1	6.1	36	-6.0
Total U.S.	17.0	100	17.0	100	0.0

- The Waxman-Sikorski bill results in major transfer payments between states as a result of the tax/subsidy program.

  -- For most of the 12-States, subsidies exceed taxes paid. Almost all the scrubbers are retrofitted in the 12-States and thus almost all the subsidy payments are received in these states, while only 43 percent of the generation taxes come from these states.

  -- For the other states, taxes exceed the subsidies received. As noted before, few scrubbers are retrofitted in these other states but they account for about 57 percent of the non-nuclear generation and, therefore, a similar percentage of the tax payments.

REGIONAL ELECTRICITY RATE IMPACTS OVER TIME
(1982 mills/kwh)

	1985	1990	1995		1996+	
	Waxman-Sikorski Bill	Waxman-Sikorski Bill	Waxman-Sikorski Bill	Cost-Effective Equivalent	Waxman-Sikorski Bill	Cost-Effective Equivalent
Pennsylvania	1.0	1.8	1.9	1.5	1.3	1.4
West Virginia	1.2	3.7	2.9	3.0	2.1	3.0
Georgia	1.1	0.9	1.1	1.4	0.5	1.3
Florida	1.0	1.6	1.1	0.4	0.5	0.4
Ohio	1.2	2.7	3.6	4.5	2.8	4.3
Michigan	1.0	0.8	0.9	0.5	0.3	0.5
Indiana	1.2	1.8	2.6	3.7	1.9	3.8
Illinois	0.9	1.3	0.9	0.7	0.6	0.7
Wisconsin	1.0	1.9	2.8	2.3	2.0	2.2
Kentucky	1.2	2.0	1.6	1.7	1.0	1.7
Tennessee	1.1	2.8	2.1	1.5	1.4	1.5
Missouri	1.2	3.7	2.9	3.2	2.2	3.0
Total 12-States	1.1	2.0	2.0	1.9	1.2	1.9
Other 19-States	0.9	0.7	0.6	0.1	0.3	0.1
Total 31-East	1.0	1.5	1.4	1.2	0.8	1.2
Total 17-West	1.2	0.8	0.7	0.1	0.1	0.1
Total U.S.	1.1	1.3	1.2	0.9	0.6	0.8

- Regional electricity rate impacts for the Waxman-Sikorski bill reflect the effects of the program over time and thus the same trends in aggregate costs noted on page 1-6:

  -- 1985 - Generation Taxes
  -- 1990 - Generation Taxes & 50 Highest Emitters Scrubbing
  -- 1995 -Generation Taxes & 50 Highest Emitters Scrubbing & Allocated Emissions Reduction Program
  -- 1996+ -50 Highest Emitters Scrubbing & Allocated Emissions Reduction Program

- There are no electricity rate impacts under the Cost-Effective Equivalent in 1985 and 1990 by assumption. In 1995 the rate impacts for this case are still lower than under the Waxman-Sikorski bill. However, after the generation tax ends in 1995, the Cost-Effective Equivalent is forecasted to result in higher electricity rate impacts in most of the 12-states due to the subsidies provided to utilities under the Waxman-Sikorski bill.

ESTIMATED ANNUAL ELECTRICITY RATE IMPACTS PER AVERAGE RESIDENTIAL CUSTOMER

(in 1982 dollars)

	1980 Average Residential Bills 1/	Forecasted Increase in 1995 2/	
		Waxman-Sikorski Bill	Cost Effective Equivalent
Pennsylvania	$494	$14	$11
West Virginia	$441	$26	$28
Georgia	$541	$12	$14
Florida	$681	$12	$5
Ohio	$521	$31	$40
Michigan	$413	$6	$4
Indiana	$493	$25	$36
Illinois	$483	$6	$5
Wisconsin	$417	$22	$18
Kentucky	$463	$17	$18
Tennessee	$603	$32	$23
Missouri	$499	$26	$29

1/ 1980 Residential Revenues ÷ 1980 Residential Customers

2/ Forecasted Change in mills/kwh (from p. 1-17) x $\frac{\text{1980 Residential Sales}}{\text{1980 Residential Customers}}$

- The electricity rate impacts in 1995 provided on page 1-17 have been restated in terms of average annual costs per residential customer in the table above. In general, these impacts are proportional to the impacts in terms of mills per kilowatt-hour shown on 1-17. However, the average amount of kilowatt-hours consumed per customer can vary considerably between states. As such, the rate impact in terms of dollars per customer (relative to mills per kwh) tends to be greater in states with high levels of kwh consumed per customer (e.g., Tennessee) and lower in states with low levels of kwh consumed per customer (e.g., Michigan).

- Annual average electricity rate impacts in 1995 were estimated using 1995 forecasted impacts in mills per kilowatt-hour and assuming average sales per customer would be the same as in 1980. The average annual residential bills in 1980 have been provided for reference purposes only. Note that changes in electricity rates forecasted in 1995 are changes from 1995 base case levels, not changes from 1980 levels.

- The above rate impacts are state-wide averages and can vary significantly between classes of customers and different utility systems within each state.

INTERPRETATION OF THE WAXMAN-SIKORSKI BILL

- There are several provisions in the Waxman-Sikorski bill which are ambiguous. Different interpretations of these provisions can have a significant effect on the forecasted impacts of this bill. See Chapter Two for a more detailed discussion.

- The scrubbing requirement for the 50 highest emitters by 1990 is ambiguous. The bill appears to require 70-90 percent reductions in emissions below 1980 levels and requires continuous control technology at these plants. This appears to allow powerplants to shift to lower sulfur coals and to scrub these coals less than 70 percent, as long as emission levels are reduced at least 70 to 90 percent below 1980 levels. However, since the bill also requires enforcement of the percent removal requirement on a comparable basis to current NSPS requirements (i.e., a technology requirement of a minimum of 70-90 percent removal) it is unclear what the basis is for determining the percent removal requirements. For the EPA analysis, a 70-90 percent technology requirement was assumed.

- The bill requires all units at each of the 50 highest emitting powerplants to be scrubbed, yet exempts new units (i.e., units on-line after 1980) installed at these plants in other sections of the bill. Hence, some NSPS units (those on-line prior to January 1, 1981) are required to scrub and others are not.

- The total required sulfur dioxide reductions by 1993 (modelled as 1995 for this analysis) are also vague. The bill stipulates a 10 million ton reduction below 1980 levels, but also appears to exempt selected emission increases at individual units associated with greater utilization or shifts to higher sulfur fuels at existing plants. This effectively results in less than a 10 million ton reduction in 1993. It is also unclear if shifts to higher sulfur coals at coal plants are exempt, as are shifts at oil or gas-fired units.

INTERPRETATION OF THE WAXMAN-SIKORSKI BILL (Continued)

- The reduction requirement is allocated to individual states based on each state's percentage of the total emissions from powerplants emitting above 1.2 pounds sulfur dioxide per million Btu. This is different than an excess emissions scheme used in the Stafford and Mitchell bills and other legislative proposals which allocate reductions based only on emissions in "excess" of a 1.2 pound sulfur dioxide rate. Despite the wording in the Waxman-Sikorski bill, the intent was apparently to use an excess emissions allocation scheme. This was the basis for allocating reductions assumed by EPA. Note that a more recent version of the Waxman-Sikorski bill introduced after this study corrected the language in the bill to use an "excess" emissions allocation scheme.

- Subsidies for 90 percent of the capital costs of retrofitting scrubbers are provided under the bill. However, it is unclear (1) whether these subsidies applied only to the 50 highest emitters or to all powerplants that opt to scrub under the emissions reduction program, and (2) whether the subsidies applied only to the initial scrubber capital costs of scrubbers or also applied to capital costs of replacing retrofit scrubbers or scrubber equipment in later years as the initial equipment has to be replaced. For the EPA analysis, the subsidies were assumed to apply to the 50 biggest emitters and all other powerplants that were forecasted to retrofit scrubbers. Also, subsidies were only assumed to apply to initial capital costs and related capital charges.

CHAPTER TWO

BASE CASE AND WAXMAN-SIKORSKI BILL SPECIFICATIONS AND INTERPRETATION

This chapter discusses the specifications and assumptions used in developing forecasts for a base case and the Waxman-Sikorski bill.

BASE CASE ASSUMPTIONS

Baseline forecasts were developed for five periods (1985, 1990, 1995, 2000 and 2010). The baseline forecasts of utility and industrial emissions, costs, fuel consumption, coal production and other measures were based on the macro energy and economic assumptions specified by EPA. These base case assumptions and forecasts are identical to those used for previous EPA analyses and first documented in a report by ICF entitled Analysis of a Senate Emission Reduction Bill (S-3041) February, 1983. The major base case assumptions are shown in Appendix E.

EPA decided to use the same base case assumptions and forecasts for the analysis of the Waxman-Sikorski bill as for the previous Senate Bill analysis[1] and for other EPA analyses conducted by ICF over the past year. This was done in order to provide a consistent set of forecasts which could be compared usefully. However, since the development of the baseline assumptions and forecasts for the Senate Bill analysis (at the end of 1982) changes have occurred which could have a significant effect on these forecasts. For more recent analyses conducted for EPA and others by ICF, a new base case has been utilized with changes in key specifications. These are discussed briefly in Chapter Three.

WAXMAN/SIKORSKI BILL ASSUMPTIONS

The Waxman-Sikorski Bill (H.R. 3400) has six basic provisions or requirements. These are:

- Retrofit scrubbers mandated for 50 Highest Emitters by 1990 (Section 185)
- Sulfur Dioxide Reduction Requirement by 1993; Credits and Exclusions (Section 181)
- Allocation of Reduction Requirement to Individual States (Section 191)
- Subsidies for Scrubber Capital Costs (Sections 181 and 186)

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[1] See ICF report to EPA, Analysis of a Senate Emission Reduction Bill (S-3041), February, 1983.

- Generation Tax to Fund Subsidies (Sections 195 and 196)
- Control of Nitrogen Oxide Emissions (Title II, Sections 201 and 202)

Each of these are discussed in the sections that follow.

Retrofit Scrubbers for 50 Highest Emitters by 1990

Section 185 of the Waxman-Sikorski bill requires that all electric utility powerplants with emission rates above 3-pounds sulfur dioxide per million Btu in 1980 be identified. The 50 highest emitting powerplants among these selected units (in terms of total sulfur dioxide emissions in 1980) are required to retrofit scrubbers or sulfur dioxide control technology by 1990. The amount of utility powerplant capacity affected by this requirement is presented in Table 2-1 and the specific powerplants assumed by EPA to be required to retrofit scrubbers are shown in Table 2-2. About three gigawatts of capacity were excluded from the requirement to retrofit scrubbers because these units are already or soon will be scrubbed under federal NSPS or SIP regulations. Approximately one gigawatt was also excluded because these units were forecasted to retire before 1995.

Section 185 also requires all units of the 50 highest emitting powerplants to scrub. For purposes of this analysis, it was assumed that new units (on line after 1980) at the 50 highest emitters would not have to be scrubbed. Requiring new units to scrub would be inconsistent with Section 181 of the bill which specifically exempts new units from having to reduce emissions. (See a later section of this chapter entitled Sulfur Dioxide Reduction Requirement by 1993/1995). A few of the fifty powerplants also had oil/gas units. These units were also assumed not to scrub for this analysis, although the bill does not appear to exempt them from this requirement.

The Waxman-Sikorski bill requires the fifty plants to install and operate "a technological system of continuous emission reduction not later than January 1, 1990". Sulfur dioxide emissions from each of the fifty plants are not "permitted to exceed in 1990 or any year thereafter" (1) 1.2 pounds per million Btu and 10 percent of the total annual sulfur dioxide emissions during the calendar year 1980 (90 percent reduction) or (2) 0.6 pounds per million Btu and 30 percent of the total annual sulfur dioxide emissions during the calendar year 1980 (70 percent reduction)."

The effect of this provision is to require each of the fifty plants to meet 70-90 percent removal requirements from 1980 levels subject to a 1.2 pound ceiling and a 0.6 pound floor similar to the current new source performance standards for new electric utility powerplants. The difference is that the Waxman-Sikorski percent removal requirements are from 1980 emission levels (i.e., tons per year) rather than a technological requirement imposed on the installed scrubbing equipment. Further, both the emission limits and the removal requirements are enforced on an annual average basis, rather than on the 30-day rolling average specified in the current NSPS requirements.

TABLE 2-1

TOTAL SPECIFIED RETROFIT SCRUBBER CAPACITY [a]
(Gw)

PA	6.6
WV	5.1
GA	3.0
FL	2.8
OH	9.0
MI	1.4
IN	7.7
IL	5.0
WI	1.0
KY	2.6
TN	6.7
AL	1.3
MS	0.8
MO	5.3
Total	58.3

Source: EPA

[a] Represents the 50 highest sulfur dioxide emitting powerplants during 1980 which also emitted sulfur dioxide at an average annual rate above 3.0 pounds per million Btu. About three gigawatts of capacity from these 50 highest emitting plants were excluded from the retrofit requirements (and this table) because these units are already scrubbed or are planning to scrub under current environmental regulations. About one gigawatt of capacity was also excluded because these units were assumed to retire before 1995.

Note: Table 2-2 on the next page shows a listing of the specific powerplants identified by EPA as those required to retrofit scrubbers.

TABLE 2-2

LIST OF "50-HIGHEST SULFUR DIOXIDE EMITTING" POWERPLANTS ASSUMED FOR THE EPA WAXMAN-SIKORSKI BILL ANALYSIS

State	Number of Powerplants	1980 SO_2 Emissions 1/ (in 10^3 tons)	Powerplants
Ohio	8	1439.1	Gavin, Muskingum, Kyger Creek, Conesville, Eastlake, Avon Lake, Burger, Ashtabula
Indiana	7	1029.3	Gibson Station, Clifty Creek, Cayuga Tanners Creek, Michigan City, Breed, Wabash River
Missouri	5	885.8	Labadie, Madrid, Montrose, Hill, Sioux
Tennessee	5	767.0	Cumberland, Gallatin, Johnsville, Sevier, Allen
Illinois	4	703.1	Baldwin, Kincaid, Coffeen, Joppa
Pennsylvania	4	675.6	Conemaugh, Hatfield, Homer City, Brunner Island
West Virginia	4	664.8	Harrison, Mitchell, Kammer, Fort Martin
Kentucky	4	623.0	Paradise, Mill Creek, Ghent, Coleman
Georgia	2	308.9	Wansley, Yates
Florida	3	285.0	Big Bend, Crist, Crystal River
Alabama	1	122.4	Colbert
Michigan	1	104.4	Campbell
Wisconsin	1	79.2	S. Oak Creek
Mississippi	1	65.7	Watson
	50	7753.3	

1/ ICF estimates based on 1980 Form 67 fuel consumption data.

The requirement of reducing 70-90 percent from 1980 emission levels implies that the actual percentage removal achieved by scrubbing in 1990 could be considerably less than the specified percentage reduction requirement. For example, a powerplant could conceivably shift to lower sulfur coals, scrub only about 30-40 percent of the sulfur dioxide in the flue gases, and still not exceed 10 percent of its 1980 emissions. However, the bill also states that the compliance for such plants shall be determined on a basis comparable to the current NSPS regulations. These regulations clearly specify a technology requirement of removing 70-90 percent of the sulfur dioxide of the coals consumed, requiring scrubbers to achieve this level of reduction. Thus, it is somewhat ambiguous as to the specific intent of these provisions in the Waxman-Sikorski bill.

For purposes of this analysis, EPA assumed that the 50 powerplants with mandated scrubbers would have to meet a technology requirement of 70 to 90 percent sulfur dioxide removal from the coals these powerplants burn. This was done instead of requiring a 70 to 90 percent reduction below 1980 levels. As noted previously, assuming 70 to 90 percent reduction below 1980 levels does not preclude powerplants from shifting to lower sulfur coals and only scrubbing a minimum amount. It was viewed by EPA that the intent of the Waxman- Sikorski scrubbing provision was to provide protection of local high sulfur coal markets and related jobs. As such, a technology requirement of 70-90 percent removal comparable to the current NSPS scrubbing requirements was deemed to be more consistent with the intent of the Waxman-Sikorski bill. A 70 to 90 percent "NSPS" technology requirement generally ensures that higher sulfur coals will be scrubbed.

Under the Waxman-Sikorski bill, the fifty powerplants that were required to scrub were forecasted to retrofit scrubbers with 90 percent removal. This is because 90 percent full scrubbing is generally more cost effective on a cost-per-ton-removed basis than partial scrubbing, particularly when a 90 percent capital subsidy is included, as shown in the table below:

TABLE 2-3

REPRESENTATIVE UTILITY SCRUBBING COSTS
(mid-1982$/Ton SO_2 Removed)

Scrubbing Option	Utility Cost Without Subsidy	Utility Cost With Subsidy
High Sulfur Coal - 90 Percent Scrub	500	250
High Sulfur Coal - 70 Percent Scrub	550	300
Medium Sulfur Coal - 90 Percent Scrub	900	450
Medium Sulfur Coal - 70 Percent Scrub	950	500
Low Sulfur Coal - 90 Percent Scrub	1850	950
Low Sulfur Coal - 70 Percent Scrub	2000	1100

The targeted emission reductions required for individual states by 1993 (modeled as 1995 for this analysis), were assumed to be achieved by the most cost effective means possible (subject to the scrubbing requirements and subsidy provisions of the bill). Hence, powerplants forced to scrub under the bill were forecasted to opt for 90 percent removal, the most cost effective scrubbing option. The higher removal capabilities of the mandated scrubbers enabled states to satisfy the additional targeted reduction requirements of the Waxman-Sikorski bill in a cost-effective manner. In general, these powerplants were also forecasted to scrub high sulfur coals because scrubbing these coals was less expensive than scrubbing medium or lower sulfur coals.

Sulfur Dioxide Reduction Requirement by 1993/1995

Section 181 (a) of the Waxman-Sikorski bill requires electric utility plants and other sources to "reduce by 1993, their rates of sulfur dioxide emissions to rates which (if achieved by those sources in 1980) would have resulted in total emissions from such sources 10 million tons below the actual total of sulfur dioxide which those sources emitted in 1980". This was interpreted by EPA as requiring a 10 million ton reduction in sulfur dioxide emissions below 1980 levels in 1993. The first year for which this reduction was required for purposes of this analysis was 1995 since forecasts were only developed for every 5-year period (i.e., 1985, 1990, 1995, 2000).

Section 181(b) allows exemptions for gross emission increases at existing and new powerplants. Section 181(b)3 states "Nothing in this part shall be construed to require any State to reduce emissions under subpart 2 of this part to take into account emission increases attributable to units or sources referred to in paragraphs (1) and (2)." This was interpreted as meaning that the selective emission increases at individual units referred to in Section 181(b)1 and 2 would be excluded:

- Emission increases at existing oil/gas fired powerplants either from increased utilization or shifts to higher sulfur fuels.
- Emission increases associated with powerplants that convert or reconvert to coal use.
- Emission increases at existing coal-fired powerplants from increased utilization.
- Emissions from new powerplants and sources (on line after 1980).

There is much uncertainty regarding the interpretation and intent of the language of the Waxman-Sikorski bill with respect to these exclusions. Of particular note is whether the emission increases at existing coal-fired powerplants from shifts to higher sulfur coals, permitted by current environmental regulations, are to be excluded. EPA interpreted the provisions as not permitting the exclusion of emission increases from such fuel shifts. If these increases had been excluded, then the emission reduction requirements would have been less (by about 0.7 million tons) and the forecasted cost impacts would be lower.

The net affect of Section 181 of the Waxman-Sikorski bill is to require a 9.6 million ton reduction from existing sources and 9.5 million tons from all sources in 1995 as shown below:

TABLE 2-4

FORECASTED SULFUR DIOXIDE REDUCTIONS UNDER THE WAXMAN-SIKORKSI BILL FROM EXISTING AND NEW SOURCES -- 1995

(in millions of tons)

Component	Sulfur Dioxide Reductions from Base -- 1995
A. 10 Million Ton Reduction	-10.0
B. Offset Net Growth	-0.7
C. Allowance for Selected Increases at Existing Plants	+1.3
D. Emissions Below Targeted Levels	-0.2
Total Existing Reductions	-9.6
E. Emission Increases From Utilization Changes At New Powerplants	+0.1
Total Reductions	-9.5

- Component A: The required 10-million-ton reduction specified in the initial provisions of the Waxman-Sikorski bill.

- Component B: An additional 0.7 million ton reduction to offset the overall growth in utility sulfur dioxide emissions at existing plants between 1980 and 1995. This growth in emissions of 0.7 million tons is the net effect of gross increases at existing powerplants due to shifts to higher sulfur coals and fuels (gas to oil), coal reconversions, greater utilization as well as other factors and gross decreases due to shifts to lower sulfur fuels, SIP compliance, lower utilization and other factors. Since the Waxman-Sikorski bill requires a 10-million-ton reduction in sulfur dioxide emissions below 1980 levels, this net growth in emissions at existing plants must be offset. (i.e., A 10.7 million ton reduction below 1995 base case levels at existing sources is equivalent to a 10 million ton reduction below 1980 levels.)

- Component C: A 1.3 million ton credit or allowance for selected increases in sulfur dioxide emissions at existing plants over 1980 levels. Certain increases in emissions at existing plants were specifically exempted under the bill. Hence, emission increases due to shifts in utilization, coal reconversions, and shifts to higher sulfur oils were not required to be offset and serve as a credit against the targeted reduction requirement.

- Component D: An additional 0.2 million ton reduction associated with some states having forecasted emissions below their required emission targets. This occurs because the emission targets under the Waxman-Sikorski bill are based on 1980 emissions and in a few states, emissions by 1995 in the base case are forecasted to fall below 1980 levels (due to SIP compliance, nuclear plants coming on line, interregional transmission, or other factors).

- Component E: Under the Waxman-Sikorski bill new powerplants are forecasted to be utilized more, increasing their emissions slightly relative to 1995 base case levels. Since the emissions from these units do not have to be offset, this increase reduces the expected reductions achieved by the bill in 1995.

Allocation of Reduction Requirements to Individual States

Each state's share of the ten million ton reduction required by 1993 is determined in Section 191 of the Waxman-Sikorski bill. According to this section, each state's share is equal to its percentage of sulfur dioxide emissions in 1980 from powerplants that emitted above a 1.2 pound sulfur dioxide per million Btu annual average rate times the ten-million ton reduction. Note that this is a different allocation procedure than used in previous acid rain bills which employed "excess" emissions schemes. In such schemes, only the actual emissions above a 1.2 pound annual emission rate were counted in determining the allocation of the emissions reductions.[1]

For this analysis, it was assumed by EPA that only "excess" emissions above a 1.2 pound sulfur dioxide emission rate were intended to be counted in allocating the 10 million ton reduction. This was done in consultation with the authors of the bill. It was their intent to keep the allocation scheme similar to the earlier Mitchell and Stafford bills which used an excess emissions scheme for allocating reduction requirements to individual states.[2]

The difference between the two allocation schemes is likely to have only a minor impact on forecasted costs and coal production on an aggregate basis. However, significant differences at the state level in emission reduction requirements and cost impacts are likely to occur. For example, states with many powerplants with very high emission rates in 1980 would generally have a greater share of the 10 million ton reduction under the excess emissions scheme than under the scheme described in Section 191, while states with powerplants with emission rates in 1980 only moderately above a 1.2 pound rate would have a smaller share.

Subsidies for Scrubber Capital Costs

The Waxman-Sikorski bill also provides for subsidies for scrubber capital costs, as noted in Sections 181 and 186. Section 181 states "Ninety percent of the capital costs of continuous emission control technology used for the purpose of such programs shall be funded through a fee on the generation of electric energy..."

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[1] Under the scheme written in the bill, a powerplant emitting at a 5.0 lb. per million Btu rate would have 5 pounds per million Btu consumed counted in determining its reduction allocation; under the 1.2 pound excess emissions scheme, the same powerplant would have 3.8 lbs. per million Btu consumed counted in determining its reduction allocation.

[2] In a recent version of the Waxman-Sikorski bill introduced after the completion of this study and initial draft reports, the language of the bill was changed to require an "excess emissions" allocation scheme.

Based on these provisions, it was assumed for this analysis that:

- Subsidies would be provided to pay for 90 percent of the capital charges of scrubbing[1]. Only the capital charges directly associated with retrofitting scrubbers or other sulfur dioxide control equipment were included. Subsidies were not applied to capital outlays needed to build additional powerplant capacity to compensate for powerplant derating due to retrofitting scrubbers.

- The fifty largest emitters that were required to scrub would receive these subsidies.

- Other powerplants that opted to scrub to meet the reduction requirements in 1993 would also receive these subsidies.

- New utility powerplants (on line after 1980) required to meet current federal or state NSPS or other limits requiring scrubbing would not be able to receive these subsidies.

There is some ambiguity with respect to the coverage of the subsidy for powerplants other than the 50 largest emitters. Section 195 permits powerplants other than the 50 largest to receive only those funds left over after the 50 largest have received their subsidies. For this analysis, it was assumed that all powerplants that opted to scrub in order to meet the reduction requirements would receive a 90 percent capital subsidy. As will be discussed in the next section, the tax mandated by the bill is inadequate to cover even the capital subsidies required by the fifty largest emitters, and thus a different tax must be specified in order to raise the necessary monies.

Generation Tax to Fund the Capital Subsidies

The capital subsidies for scrubbers and sulfur dioxide control equipment retrofitted to meet the control and emission reduction requirements of the bill were assumed to be funded from an Acid Deposition Control Fund, as discussed in Sections 195 and 196. The Acid Deposition Control Fund is to be funded through a tax on non-nuclear generation (i.e., electricity generation from fossil fuels, hydro, geothermal and renewable sources) plus electricity imports (from Canada and Mexico). The tax can be characterized as noted in Table 2-5 on the next page.

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[1] It was assumed for this analysis that 90 percent of the capital "charges" associated with retrofitting scrubbers would be subsidized. Capital charges include the initial construction expenditures as well as the future income taxes and associated revenue requirements from such investments. The present value of capital charges are somewhat higher than the actual scrubber capital construction expenditures by about 13 percent. It is not clear what charges would or would not be allowed under the Waxman-Sikorski bill. If only the capital construction expenditures were financed by the subsidies then the subsidy requirements would be about 13 percent less and the costs to utilities correspondingly higher.

TABLE 2-5

GENERATION TAX - WAXMAN SIKORSKI BILL

Coverage:	48 States
Timing:	Commences at the beginning of 1984, Terminates at the end of 1995.
Level:	1 Mill per kilowatt-hour
Terms:	Nominal (not indexed to inflation)
Type of Generation:	All electricity generated in or imported to the U.S except for nuclear generation or electricity used at the electricity generating facility

There are several uncertainties with respect to this tax. First and foremost, a 1 mill per kilowatt-hour tax on non-nuclear generation is inadequate to fund the subsidies forecasted to be required under the Waxman-Sikorski bill. As is discussed in Chapter Three, the tax requirement was redesigned for this analysis to ensure the subsidy payments could be funded. Second, the tax on generation excluded nuclear generation but did not exclude hydro, geothermal and other non-polluting generation technologies.

Control of Nitrogen Oxide Emissions

A final provision of the Waxman-Sikorski bill is to require more stringent nitrogen oxide emission standards at (1) new utility powerplants (2) trucks and truck engines. Sections 201 and 202 under Title II of the bill discuss these provisions.

New utility powerplants must meet more stringent nitrogen oxide limits than required for new powerplants under the current new sources performance standards (NSPS). The bill requires new powerplants which commence construction after the date of enactment of the bill to meet these revised standards. The revised standards are:

- For new bituminous plants -- 0.4 pounds nitrogen oxide per million Btu (versus current NSPS of 0.6).
- For new subbituminous plants -- 0.3 pounds nitrogen oxide per million Btu (versus current NSPS of 0.5).

About 20 gigawatts of new powerplant capacity is forecasted to be affected by 1995 by the more stringent nitrogen oxide limits assuming the bill is enacted in 1984. Nitrogen oxide emissions are forecasted to be reduced only slightly (by about 0.1 million tons) and utility annual costs are estimated to rise only slightly, by between $10 and $50 million (in mid-1982$) as a result of these provisions. This is at most about 1 percent of the forecasted annual cost impacts of the Waxman-Sikorski bill in 1995. These impacts are summarized below:

TABLE 2-7

ESTIMATED IMPACTS OF TIGHTER NITROGEN OXIDE LIMITS ON UTILITY EMISSIONS AND COSTS -- 1995

	1980	Base 1995	Waxman Bill 1995
Total Utility NO_x Emissions (million tons)	6.7	8.6	8.5
Additional Annual Costs (billions of 1982 $)	-	-	+0.01-+0.05
New Powerplant Capacity Affected (Gw)	-	-	20

The impact of the nitrogen oxide limitation on new trucks and truck engines (commencing in model year 1986) was not analyzed. This was beyond the scope of the EPA analysis.

CHAPTER THREE

GENERATION TAXES AND SULFUR DIOXIDE CONTROL EQUIPMENT SUBSIDIES

This chapter discusses the electricity generation taxes specified under the Waxman-Sikorski bill, and electricity generation taxes forecasted to be required to fund the desired subsidies. The electricity rate impacts and cash flow consequences of the tax and subsidy are also presented. In addition, the chapter focuses on the design and economic issues associated with subsidies for scrubbers.

GENERATION TAX

A tax on electricity generation was specified under the Waxman-Sikorski bill to fund capital subsidies provided to utilities under the bill. These subsidies were to fund 90 percent of the capital charges incurred in retrofitting sulfur dioxide control equipment on existing powerplants.

The electricity generation tax designed to fund the scrubber capital subsidies is summarized in the table below:

TABLE 3-1

GENERATION TAX SPECIFICATIONS-
WAXMAN-SIKORSKI BILL

Coverage:	48-States
Timing:	Beginning of 1985 to End of 1995
Level:	1 mill per kilowatt hour
Terms:	Nominal (not indexed to inflation)
Type of Generation:	All but nuclear; also includes electricity imports

The tax is specified to fund 90 percent of the capital charges for all sulfur dioxide control equipment. However, as discussed in Chapter Two, the bill also specifies that if the tax is insufficient to provide funding for both the fifty highest emitters and other powerplants, the 50 highest emitters should be funded first.

The tax, as specified, is inadequate to cover 90 percent of the capital costs for both the 50 highest emitters and other powerplants that opt to scrub. Moreover, it does not provide sufficient funds for subsidies to only the 50 highest emitters.

TABLE 3-2

GENERATION TAX AND REQUIRED SUBSIDIES-WAXMAN-SIKORSKI BILL

(in billions of mid-1982 $)

	Capital Subsidies Required		
Total Generation Tax Revenues	50 Highest Emitters	Other	Total
16.3	19.9	2.4	22.3

Revenues from the generation tax are about $3.6 billion lower than the capital subsidies required by the 50 highest emitters and $6.0 billion less than total capital subsidies required by both the 50 highest emitters and other powerplants that would opt to scrub (if provided a 90 percent capital subsidy). As such, some of the subsidies would have to remain unfunded, or be funded out of general tax revenues or the generation tax would have to be respecified. For this analysis, the latter case was selected.

Generation Tax-Specifications for This Analysis

For this analysis of the Waxman-Sikorski bill, it was assumed that a generation tax would be specified that was adequate to fund subsidies for both the 50 highest emitters required to scrub and other powerplants opting to scrub. The design of the generation tax was identical to that specified by the Waxman-Sikorski bill except that the level of the tax was increased, as noted below:

TABLE 3-3

REVISED GENERATION TAX SPECIFICATIONS-WAXMAN-SIKORSKI BILL

Coverage:	48-States
Timing:	Beginning of 1985 to End of 1995
Level:	1.37 mills per kilowatt hour
Terms:	Nominal
Type of Generation:	All but nuclear; also includes electricity imports
Repayment:	None

There are a number of important issues and questions regarding the structure of a generation tax. These include:

- What type of tax should be used? If a generation tax is specified, what types of generation should be taxed -- all generation, all non-nuclear generation, or fossil generation only? Can electricity imports be taxed and are they taxed on the basis of the amount transmitted or received?
- When should the tax be initiated, and how long should it be maintained?
- How high should the tax be -- sufficient to ensure full coverage of expenditures (no negative outflows)?
- How should the tax be specified -- flat rate (constant in nominal terms) or indexed to inflation (constant in real terms)?
- Would recipients have to repay the funds used for scrubbers, and if so, at what interest rate and over what repayment period?

The type of tax specified is perhaps the most critical question, with important cost and distribution ramnifications. A generation tax as specified under the Waxman-Sikorski bill tends to spread costs relatively evenly across the U.S. on the basis of electricity consumption. Alternative tax schemes have been proposed which would tax sulfur or sulfur dioxide emissions. Such an approach tends to concentrate costs in states with high sulfur dioxide emissions, and could provide incentives for certain states to pursue further emission reductions (depending on the level of the tax and the reduction allocated to that state). Other approaches would provide funds for the subsidies out of general tax revenues or from a Btu-tax on all energy consumption regardless of consumer. Such approaches could spread costs in a variety of ways depending on how the incremental revenues were raised.

If a generation tax is selected, the type of generation taxed has an important effect on the distribution of costs. Taxing all non-nuclear generation as is specified in the Waxman-Sikorski bill distributes more of the costs to states with relatively little nuclear power (i.e., many Western States) and less costs to states with large amounts of nuclear power (i.e., some Eastern States). Taxing only fossil generation (i.e., excluding nuclear _and_ hydroelectric, geothermal and other renewables) would result in less taxes being paid in many Western states than a non-nuclear generation tax, because of the high levels of hydropower in those states.

The timing of the tax is also an important element to consider. The Waxman-Sikorski bill spreads the tax receipts over an eleven year period, presumably to keep year to year cost or electricity rate impacts relatively low. A longer time period (e.g., 1985-2000) could reduce the year to year impacts even more, although the present value of costs or electricity rate impacts would be the same. A shorter time period (e.g., 1985-1990) would increase the year to year impacts, but would have the advantage of ensuring the cost impacts of the tax would occur prior to the cost and rate effects of complying with the mandated scrubbing and emission reduction requirements of the bill.

The level of the tax will not only affect the amount of subsidies that can be provided, but will also have important cash flow consequences, as will be discussed in the next section. Specifying the tax in real terms (indexed to inflation) might be preferable to a nominal or flat-tax (as is specified under Waxman-Sikorski), since unanticipated increases in the inflation rate and thus the costs of building scrubbers and required subsidies would be compensated for by a higher nominal tax rate.

Repayment of the subsidy funds was not assumed for this analysis and was not specified under the bill. For alternative subsidy schemes which provide loans with repayment terms the benefits from the subsidy will be reduced and the amount of scrubbers retrofitted will be reduced.

Cash Flow Consequences of the Generation Tax

The graph on the following page (Figure 3-1) shows the cash flow consequences of subsidizing retrofit scrubbers from the generation tax fund specified in Table 3-3. The following basic assumptions were employed:

- Non-nuclear generation forecasts (plus electricity-imports) were developed using the base case forecasts from ICF's Coal and Electric Utilities Model (CEUM) employed in this analysis. These generation forecasts were used in turn to estimate cash inflows or tax receipts.

- Retrofit scrubber capital costs and thus subsidies[1] (i.e., cash outflows) were assumed to be expended over a three year period prior to the scrubber's operations. Twenty-five, fifty and twenty-five percent of the scrubber capital costs were assumed to be expended in the three year period. Scrubbers retrofitted at the fifty highest emitters which were forced to scrub by 1990 were assumed to be completed in equal amounts at the end of 1987, 1988 and 1989. The remaining scrubber capacity associated with those powerplants opting to scrub in 1995 was assumed to be added in equal proportions in 1992, 1993 and 1994. (Note for this analysis, it was assumed that the 10 million ton reduction under the bill was required by 1995 rather than 1993).

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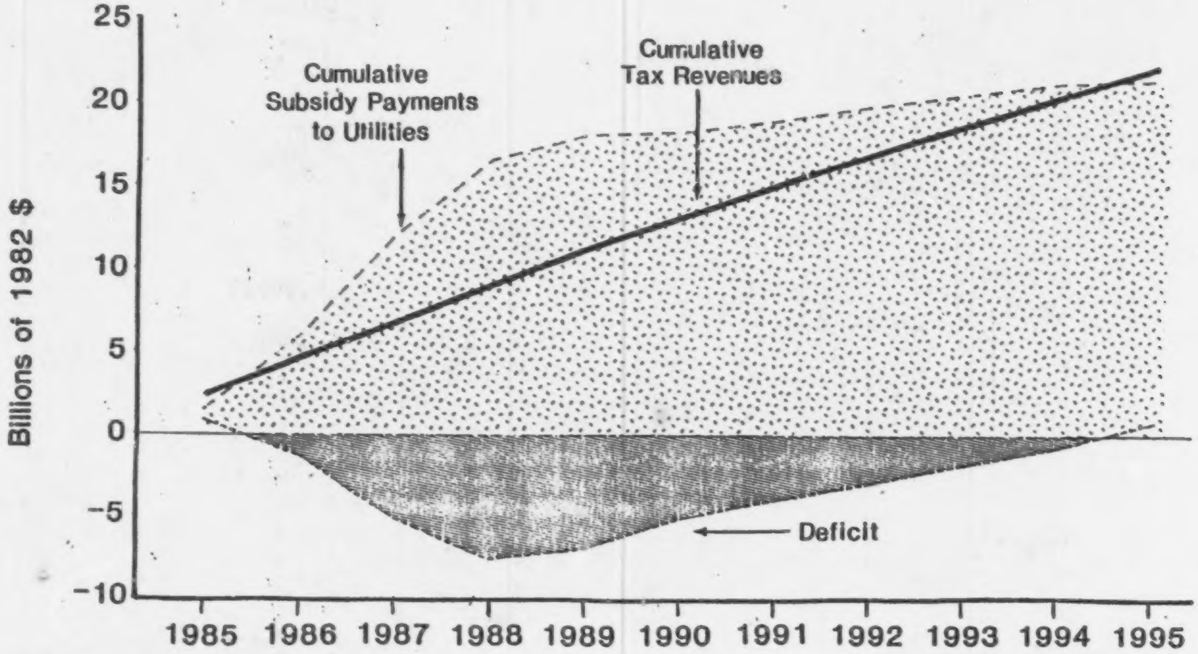
[1] As noted earlier, subsidies were designed to cover 90 percent of the capital "charges" associated with retrofitting a scrubber.

FIGURE 3-1

GENERATION TAX REVENUES AND PAYMENTS TO UTILITIES



- The fund was assumed to earn (or pay, when borrowing was required to cover cash outlays) a 2.5 percent real rate of return.

The net cash flows shown in Figure 3-1 reflect the structure of the tax, the bill's requirements, and the above assumptions. Since the tax was designed to just cover the required subsidies, net cash flows equal zero at the end of 1995. At this point, all subsidy payments have been made and all taxes have been collected. However, most of the subsidy payments are required prior to 1990 and the tax receipts are collected over an eleven year period with less than half the funds collected by 1990. Consequently, significant net outflows occur in the early years (particularly in 1988 and 1989) forcing the fund to borrow. The largest annual shortfall occurs in 1988 with a requirement to borrow 7.5 billion in mid-1982 dollars. The fund's debt is amortized over the 1990 to 1995 period reaching zero at the end of 1995.

Different generation tax schemes could ensure that net outflows from the funds would not occur, therefore eliminating the need to borrow. One option would be to set a higher tax-rate between 1985 and 1989 which would effectively cover the capital subsidies for scrubbers required to be on line by the beginning of 1990, and set a much lower tax rate to cover subsidy expenditures for the remaining scrubbers brought on-line in 1995.

It is important to recognize that while the present value of the fund will be the same from the standpoint of the federal government under each of these options (assuming a 2.5 percent real rate of return and net cash flows equal to zero at the end of 1995), many of those paying taxes into the fund will not be indifferent. Industrial electricity consumers, for example, typically have much higher required real rates of return (or real cost of capital) than utilities or the federal government. As such, these electricity consumers would prefer options which have lower taxes in the near term and higher taxes in the long term.

Electricity Rate Impacts of the Generation Tax

The electricity rate impacts associated with the implementation of the Waxman-Sikorsii bill's generation tax and emission reduction program are summarized in Tables 3-4, 3-5 and 3-6. Table 3-4 shows the average rate impacts of only the 1.37 mills per kilowatt hour generation tax by state in 1985, 1990 and 1995. Rate impacts differ regionally reflecting the exclusion of nuclear generation from the tax and thus lower rate impacts in states with high levels of nuclear generation. Rate impacts shown here have been averaged across the state, based on each state's forecasted non- nuclear generation plus imports from Canada and Mexico. The state average will not be representative of individual system impacts where the individual system characteristics differ markedly from the state profile.

Electricity rate impacts shown in Tables 3-5 and 3-6 include the utility costs of meeting the emission reduction requirements of the bill as well as the impact of the generation tax. Thus, the state-by-state rate impacts reflect the total forecasted impact of the Waxman-Sikorski bill on electric utilities and ratepayers. Rate impacts are presented in 1985, 1990, 1995 and 1996. The highest impacts are in 1995 when the tax is being collected and utilities are required to meet the Waxman-Sikorski emission reduction requirements. In 1996, when the tax is ended, the rates increase less.

TABLE 3-4

AVERAGE ELECTRICITY RATE IMPACTS OF WAXMAN-SIKORSKI GENERATION TAX ONLY

(mid-1982 mills/kwh)

Region	1985	1990	1995
MV	0.9	0.5	0.4
MC	0.8	0.7	0.5
New England	0.8	0.6	0.5
NY	1.1	0.8	0.6
PA	1.0	0.8	0.5
NJ	0.6	0.4	0.5
Middle Atlantic	1.0	0.7	0.5
MD	1.0	0.8	0.6
VA	0.7	0.6	0.4
WV	1.2	1.0	0.8
CA	0.9	0.6	0.5
GA	1.1	0.8	0.6
FL	1.0	0.8	0.6
South Atlantic	1.0	0.7	0.6
OH	1.2	0.9	0.6
MI	1.0	0.7	0.5
IN	1.2	1.0	0.7
IL	0.9	0.6	0.4
WI	1.0	0.8	0.6
East North Central	1.1	0.8	0.6
KY	1.2	1.0	0.8
TN	1.1	0.8	0.6
AL	0.8	0.6	0.5
MS	1.0	0.7	0.6
East South Central	1.1	0.8	0.6
MN	0.8	0.6	0.6
IA	1.2	0.9	0.7
MO	1.2	0.9	0.7
AR	0.8	0.7	0.6
LA	1.0	0.7	0.6
West Bank Of Mississippi	1.1	0.8	0.6
31-Eastern States	1.0	0.8	0.6
DA	1.3	1.1	0.8
KN	1.1	0.9	0.6
West North Central	1.2	0.9	0.7

TABLE 3-4 (Continued)

AVERAGE ELECTRICITY RATE IMPACTS OF WAXMAN-SIKORSKI GENERATION TAX ONLY

(mid-1982 mills/kwh)

Region	1985	1990	1995
OK	1.2	1.0	0.8
TX	1.2	0.9	0.7
West South Central	1.2	0.9	0.7
MT	1.3	1.1	0.8
WY	1.2	1.0	0.8
ID	1.2	1.0	0.8
CO	1.2	1.0	0.7
NM	1.2	1.0	0.8
UT	1.2	1.0	0.8
AZ	1.1	0.7	0.5
NV	1.2	1.0	0.8
Mountain	1.2	1.0	0.8
WO	1.2	0.9	0.7
CA	1.1	0.8	0.6
Pacific	1.2	0.9	0.7
17-Western States	1.2	0.9	0.7
Total U.S.	1.1	0.8	0.6

TABLE 3-5

AVERAGE ELECTRICITY RATE IMPACT OF TOTAL WAXMAN-SIKORSKI PROGRAM
(mid-1982 mills/kwh)

Region	1985	1990	1995	1996
MV	0.9	0.5	0.5	0.1
MC	0.8	0.7	0.4	0
New England	0.8	0.7	0.4	0
NY	1.1	0.8	0.7	0.1
PA	1.0	1.8	1.9	1.3
NJ	0.6	0.5	0.5	0.1
Middle Atlantic	1.0	1.2	1.2	0.7
MD	1.0	0.7	1.2	0.5
VA	0.7	0.4	0.3	-0.1
WV	1.2	3.7	2.9	2.1
CA	0.9	0.5	0.4	0
GA	1.1	0.9	1.1	0.5
FL	1.0	1.6	1.1	0.5
South Atlantic	1.0	1.3	1.1	0.5
OH	1.2	2.7	3.6	2.8
MI	1.0	0.8	0.9	0.3
IN	1.2	1.8	2.6	1.9
IL	0.9	1.3	0.9	0.6
WI	1.0	1.9	2.8	2.0
East North Central	1.1	1.7	2.1	1.5
KY	1.2	2.0	1.6	1.0
TN	1.1	2.8	2.1	1.4
AL	0.8	0.3	0.1	-0.2
MS	1.0	3.3	2.2	1.6
East South Central	1.1	2.0	1.4	0.8
MN	0.8	1.0	0.5	0
IA	1.2	0.9	1.3	0.6
MO	1.2	3.7	2.9	2.2
AR	0.8	0.7	0.6	0
LA	1.0	0.7	0.6	0
West Bank of Mississippi	1.1	1.7	1.2	0.6
31-Eastern States	1.0	1.5	1.4	0.8
DA	1.3	1.1	1.2	0.4
KN	1.1	0.8	0.5	-0.1
West North Central	1.2	0.9	0.7	0.1

TABLE 3-5 (Continued)

AVERAGE ELECTRICITY RATE IMPACT OF TOTAL WAXMAN-SIKORSKI PROGRAM

(mills/kwh)

Region	1985	1990	1995	1996
OK	1.2	1.0	0.9	0.2
TX	1.2	0.9	0.8	0.1
West South Central	1.2	0.9	0.8	0.1
MT	1.3	1.2	0.9	0.1
WY	1.2	0.8	0.6	-0.2
ID	1.2	1.0	0.8	0
CO	1.2	1.0	1.1	0.3
NM	1.2	0.6	0.8	0
UT	1.2	0.4	1.0	0.1
AZ	1.1	0.2	0.5	0
NV	1.2	0.1	0.3	-0.4
Mountain	1.2	0.6	0.7	0
WO	1.2	0.9	0.8	0.1
CA	1.1	0.8	0.6	0
Pacific	1.2	0.9	0.7	0
17-Western States	1.2	0.8	0.7	0.1
Total U.S.	1.1	1.3	1.2	0.6

TABLE 3-6

PERCENT CHANGE IN ELECTRICITY RATES -- TOTAL WAXMAN-SIKORSKI PROGRAM 1/

(%)

Region	1980 Average Residential Rates (mid-1982 mills/kwh)	1985	1990	1995	1996
MV	68	1.3	0.7	0.7	0.1
MC	79	1.0	0.9	0.5	-
New England	76	1.1	0.9	0.5	-
NY	88	1.3	0.9	0.8	0.1
PA	65	1.5	2.8	2.9	2.0
NJ	91	0.7	0.5	0.5	0.1
Middle Atlantic	84	1.2	1.4	1.4	0.8
MD	65	1.5	1.1	1.8	0.8
VA	64	1.1	0.6	0.5	(0.2)
WV	48	2.5	7.7	6.0	4.4
CA	49	1.8	1.0	0.8	-
GA	51	2.2	1.8	2.2	1.0
FL	62	1.6	2.6	1.8	0.8
South Atlantic	57	1.8	2.3	1.9	0.9
OH	59	2.0	4.6	6.1	4.7
MI	62	1.6	1.3	1.5	0.5
IN	49	2.4	3.7	5.3	3.9
IL	66	1.4	2.0	1.4	0.9
WI	54	1.9	3.5	5.2	3.7
East North Central	59	1.9	2.9	3.6	2.5
KY	43	2.8	4.7	3.7	2.3
TN	39	2.8	7.2	5.4	3.6
AL	52	1.5	0.6	0.2	(0.4)
MS	51	2.0	6.5	4.3	3.1
East South Central	45	2.4	4.4	3.1	1.8
MN	49	1.6	2.0	1.0	-
IA	56	2.1	1.6	2.3	1.1
MO	55	2.2	6.7	5.3	4.0
AR	52	1.5	1.3	1.2	-
LA	47	2.1	1.5	1.3	-
West Bank of Mississippi	51	2.2	3.3	2.4	1.2
31-Eastern States	60	1.7	2.5	2.3	1.3
DA	45	2.9	2.4	2.7	0.9
KN	52	2.1	1.5	1.0	(0.2)
West North Central	50	2.4	1.8	1.4	0.2

TABLE 3-6 (Continued)

PERCENT CHANGE IN ELECTRICITY RATES -- TOTAL WAXMAN-SIKORSKI PROGRAM 1/ (%)

Region	1980 Average Residential Rates (mid-1982 mills/kwh)	1985	1990	1995	1996
OK	47	2.6	2.1	1.9	0.4
TX	55	2.2	1.6	1.5	0.2
West South Central	53	2.3	1.7	1.5	0.2
MT	31	4.2	3.9	2.9	0.3
WY	34	3.5	2.4	1.8	(0.6)
ID	32	3.8	3.1	2.5	-
CO	52	2.3	1.9	2.1	0.6
NM	67	1.8	0.9	1.2	-
UT	62	1.9	0.6	1.6	0.2
AZ	68	1.6	0.3	0.7	-
NV	54	2.2	0.2	0.6	(0.7)
Mountain	53	2.3	1.1	1.3	-
WO	25	4.8	3.6	3.2	0.4
CA	65	1.7	1.2	0.9	-
Pacific	48	2.5	1.9	1.5	-
17-Western States	51	2.4	1.6	1.4	0.2
Total U.S.	57	1.9	2.3	2.1	1.1

1/ Calculated as follows for each year:

$$\left[\frac{\text{Forecast Year Waxman-Sikorski Annualized Cost} - \text{Forecast Year Base Case Annualized Cost}}{\text{Forecast Year Electricity Sales}}\right] \div \left[\begin{array}{c}\text{1980 Average}\\ \text{Residential}\\ \text{Electricity}\\ \text{Price}\end{array}\right]$$

Note that these impacts represent changes in rates based on annualized costs. Although annualized costs typically differ significantly from first-year revenue requirements, the capital subsidies mitigate this difference, making the percent changes relatively comparable. This is because the major difference between first-year revenue requirements and annualized costs is the regulatory treatment of utility capital investments. This treatment results in high rate increases in the early years of capital equipment and low rate impacts toward the end of its useful life. With subsidies paying for 90 percent of the capital costs, most of the additional capital costs will not be placed into a utility's rate base, thereby avoiding most, if not all, of the higher first-year rate impacts.

Also, the rates as measured for this analysis reflect statewide averages which can be higher or lower than those experienced by individual utilities within each state or CEUM demand region. This is because emission reductions and costs may be concentrated within a state or region at one or a few utility systems while other utility systems within the state have few reductions and costs. This will depend, however, on how each of the states choose to allocate the costs of meeting their emission reduction requirements across the state's population.

Finally, the electricity rate impacts shown in Tables 3-5 and 3-6 show only the direct effects of the Waxman-Sikorski bill on electricity consumers. The macro-economic effects of both the taxes and compliance costs of the Waxman-Sikorski bill were not assessed for this analysis.

DESIGN OF THE SULFUR DIOXIDE CONTROL TECHNOLOGY SUBSIDIES

The capital subsidies for sulfur dioxide control equipment specified under the Waxman-Sikorski bill were presumably an attempt to mitigate two of the major concerns associated with large scale emission reduction proposals:

- Expected major losses in existing high-sulfur coal production with attendant mine closings and job shifts to other producing regions, particularly for the high sulfur regions of the Midwest and Northern Appalachia.
- A forecasted concentration of cost impacts and, therefore, electricity rate impacts in the Midwestern states since these states have the largest share of allocated emission reduction requirements and also have the more cost-effective opportunities to reduce sulfur dioxide emissions in the 31-Eastern states.

As has been discussed in this report, capital subsidies for control equipment provided by the Waxman-Sikorski bill can ameliorate these concerns to a large degree. Subsidies will encourage utilities to retrofit scrubbers and continue to use higher sulfur coals. This in turn reduces the shifts to lower sulfur coals, thus maintaining forecasted higher sulfur coal production in 1995 at or above existing levels. Since most of the emission reductions generally are required to come from the higher emitting Midwestern states and most of the reductions are forecasted to occur through scrubbing, a capital subsidy would reduce the concentration of cost increases and electricity rate impacts in some of these states.

In addition to potential funding issues discussed previously, capital subsidies have the major disadvantage of increasing total costs (including the subsidies) of meeting the emission reduction requirements. This is because the subsidies encourage utilities to pursue higher cost emission reduction options than they would have chosen in the absence of the subsidies (i.e., scrubbing in lieu of shifting to lower sulfur coals).

Also, the capital cost subsidy not only encourages the use of scrubbers or other control technologies but also biases utilities towards retrofitting scrubbers with the lowest possible operating costs, with little concern for the level of capital costs. As such, it is likely that a 90 percent capital subsidy would result in some scrubbers being retrofitted with lower operating costs but higher total costs than scrubbers that would have been retrofitted in the absence of capital subsidies. The additional costs associated with this bias have not been assessed for this analysis but are worthy of further study.

Other subsidy schemes could alleviate this problem. One possible option, a dollar-per-ton removed subsidy, would provide utility powerplants with a certain dollar amount for every ton of sulfur dioxide emission reduced from the coal that was scrubbed. A dollar-per-ton-removed subsidy would generally ensure that the more cost effective control technologies would be retrofitted and not bias utilities towards "gold plating".

In addition, capital subsidies could affect the amount of taxes collected by the federal government relative to situations where the same number of scrubbers are retrofitted and no subsidies are provided. If utilities are permitted to subsidize portions of retrofit scrubber capital, then future tax payments to the government would be lower since the government will have foregone its tax on the returns on equity investments in the retrofit scrubbers. In addition, it is currently unclear how the subsidies of scrubber capital expenditures would affect investment tax credits and the capital basis for accelerated depreciation.

All scrubber cost subsidies regardless of their design will result in higher total costs, because they encourage utilities to make less cost-effective emission reduction decisions. Higher costs are traded for the protection of high sulfur coal production and jobs, a more even distribution of costs, and to minimize the economic impacts on regional economies. It is possible that similar results could be achieved at lower cost than under the Waxman-Sikorski bill through a direct transfer of costs between states (by changing the allocation of reductions and permitting interstate trading), through funds being transferred directly to coal miners and mine operators, and/or through alternative subsidy/taxation schemes. Inevitably, such alternatives also force difficult distribution and equity issues to be addressed directly. An analysis of the issues related to alternative approaches to protect local coal markets and economic activity was beyond the scope of the EPA study.

CHAPTER FOUR

CAVEATS AND UNCERTAINTIES

There are a number of caveats, assumptions, and uncertainties which have an important effect on the findings of this analysis. These are discussed in the sections that follow:

DIRECT COSTS AND NEAR-TERM CONSTRAINTS NOT ANALYZED

Some of the direct costs of the Waxman-Sikorski bill and Cost-Effective Equivalent were not measured for this analysis. These potential costs could be significant but their exact magnitude is uncertain. These were beyond the scope of this EPA analysis, although they have been the subject of other analytical efforts by ICF.

- **Short-Run Manufacturing Bottlenecks** -- were not assessed for this analysis. These are likely to be very significant because of the Waxman-Sikorski requirement to retrofit scrubbers on the 50 highest emitting plants by 1990 (i.e., about 60 gigawatts of capacity). Another analysis by ICF indicates that demand of more than 20 gigawatts by 1990 cannot be accommodated given the current engineering capability of the scrubber industry in the U.S.[1] As such it may not be feasible to retrofit scrubbers on the highest emitting plants by 1990. At a minimum, the costs of installing and operating these scrubbers are likely to be greater than estimated herein and the performance of these scrubbers could be less than assumed due to poor design and construction.

- **Short-Run Production and Transportation of Bottlenecks** -- were not assumed in this analysis. Rather, the analysis assumed that market prices would come into equilibrium and excluded any short-run disequilibrium effects. Short-run production or transportation constraints could influence the costs of any major emission reduction program with significant 1990 requirements. This is particularly true for the Cost-Effective Equivalent case because of the significant shifts in coal production and shipments forecasted.[2]

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[1] See ICF report prepared for Alliance for Clean Energy entitled Analysis of Cost-Effective, Phased-In Reductions of Sulfur Dioxide Emissions December 1983.

[2] Ibid.

- **Low Sulfur Oil Prices** -- were not assumed to increase in response to greater forecasted demand for utilities for low-sulfur residual oil, particularly under the Cost-Effective Equivalent case. However, these prices may increase resulting in higher costs for all users of this low sulfur product.

- **Gas Prices** -- were not assumed to increase for this analysis. Gas consumption was also not assumed to increase. To the extent utilities are able to obtain additional gas supplies, the costs forecasted for the Waxman-Sikorski bill and Cost-Effective Equivalent may be overstated somewhat. However, gas prices would increase in response to increased demand for gas and for competing fuels such as low-sulfur oils. If natural gas prices increased $0.10 per million Btu and 20 quads were consumed nationally, the national cost of the price increase to consumers would be $2 billion.

- **Conservatism in Implementation** -- For this analysis, it was assumed that states would attempt to enforce the Waxman-Sikorski bill and Cost-Effective Equivalent by requiring utilities and industrial sources to meet the exact level of reduction mandated under the bill. States may require more reductions than stipulated in the law or may employ implementation schemes that result in more reductions. Utilities may also be conservative if faced with substantial enforcement penalties and reduce more. If conservatism resulted in an extra 10 percent reduction (about one million tons), the annual incremental costs would approach another $1 billion.

- **Emissions Trading** -- For the Waxman-Sikorski bill and the Cost-Effective Equivalent, trading of emission reductions was assumed to occur (i.e., between and within states for the Cost-Effective Equivalent and within states for the Waxman-Sikorski bill). Such trading ensures that more cost-effective reductions will occur. To the extent trading within and between states is not permitted or infeasible because of political and institutional limitations, the forecasted costs of the Waxman-Sikorski bill will be higher and the forecasted costs of the Cost-Effective Equivalent will be significantly higher. Based on a previous analysis conducted for EPA of an emission reduction bill with similar reduction requirements as Waxman-Sikorski, the annual cost savings associated with permitting interstate trading versus only permitting intrastate trading is likely to be about $0.2 billion.[1]

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[1] See the ICF report entitled Analysis of a Senate Emission Reduction Bill (S-3041) February, 1983.

INDIRECT COSTS AND BENEFITS NOT MEASURED

Many of the indirect costs and benefits of the Waxman-Sikorski bill and Cost-Effective Equivalent were not measured for this analysis. These include the following types of costs and benefits:

- **Administrative and Transaction Costs** -- could be significant under the Waxman-Sikorski bill due to the complicated procedures associated with establishing emission reduction targets, and the costs of administering the subsidies and taxes. Transaction costs could be significant under the Cost-Effective Equivalent because of the amount of trading forecasted to take place and the attendant regulatory mechanisms needed to implement such a trading program.
- **Lost Investment in Existing Mining Operations** -- will depend on the extent to which regional coal production falls below existing levels. Very little lost investment would be expected under the Waxman-Sikorski bill; some losses, particularly in the Midwest and Northern Appalachia, could occur under the Cost-Effective Equivalent case because of the major shifts in regional coal production.
- **Indirect and Regional Impacts of Lost Mining Jobs** -- will depend on the shifts in regional coal production and the attendant changes in coal mining employment. Greater impacts would be expected under the Cost-Effective Equivalent because of its greater impact on regional coal production.*
- **Costs of Abrogating Long-Term Contracts** -- could be significant depending on the specific provisions of various existing coal contracts. These costs would likely be more significant under the Cost-Effective Equivalent case. These have not been addressed in this analysis. To the extent these become important, the cost impacts identified in this analysis would understate the expected impacts.

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* Note that "lost" jobs in the higher sulfur coal producing regions can and should be calculated in two different ways depending upon the impact being measured. If the concern is the number of currently employed miners who could lose their jobs in a particular region in the future, changes in regional mining employment relative to 1980 (or current) levels should be calculated with some adjustment made for "normal" attrition of the job force due to miner and mine retirements. However, if the concern is the level of overall economic activity within a region in 1995, changes in mining employment (as well as in manufacturing and transportation employment) should be measured relative to 1995 base case levels.

- **Indirect and Regional Impacts of New Mining, Transportation, and Manufacturing Jobs** -- will vary with the forecasted increases in regional mining and transportation employment and increases in retrofit scrubbers. While more new mining and transportation jobs are forecasted under the Cost-Effective Equivalent case, more manufacturing jobs (due to the retrofit scrubbers being built) would likely result from the Waxman-Sikorski bill.

- **Benefits of Emission Reductions** -- should be weighed against the costs of these reductions. Most appropriately, the marginal benefits of the last ton of reduction should be compared with the marginal costs. The cost-effectiveness of the emission reduction program should be considered in light of the acid deposition, health related effects, visibility improvements, agricultural and materials damage improvements, and other benefits forecasted to result.

SULFUR DIOXIDE CONTROL EQUIPMENT COSTS AND ASSUMPTIONS

Sulfur dioxide control equipment costs and other assumptions will have an important impact on the costs and coal production impacts of various emission reduction programs, particularly the Waxman-Sikorski bill. The scrubber costs, removal efficiencies, retrofit factor and other assumptions are based on EPA estimates and are identical to those scrubber assumptions documented in a previous EPA analysis.[1] Retrofit scrubber costs are presented on the next page in Table 4-1.

Sulfur dioxide control costs, removal efficiencies, retrofit factor, scrubber types and new control technology assumptions and their impact on the forecasted costs and coal production impacts of the Waxman-Sikorski and Cost-Effective Equivalent are discussed below.

- **Costs** - The level of scrubber costs will significantly affect the forecasted costs of the Waxman-Sikorski bill. Higher or lower scrubber costs will accordingly raise or lower the forecasted cost impacts.

  The relative costs of scrubbing high versus lower sulfur coals could influence forecasted coal production. If the costs of scrubbing lower sulfur coals were much cheaper than assumed currently, some powerplants forced or opting to scrub under the Waxman-Sikorski bill might choose to scrub medium or low sulfur coals, with less protection resulting for high-sulfur coal production.

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[1] See ICF report prepared for EPA entitled Analysis of a Senate Emission Reduction Bill (S-3041) February, 1983.

TABLE 4-1

RETROFIT SCRUBBER COSTS FOR EXISTING UTILITY POWERPLANTS

	Coal After Preparation lbs. $SO_2/10^6$ Btu (Long-Term Average)						
	0.90	1.08	1.67	2.50	3.33	5.00	6.67
Scenario Specifications							
A. Annual SO_2 Emission Limit (lbs./10^6 Btu)	0.08	0.11	0.17	0.25	0.33	0.50	0.67
B. Annual SO_2 Removed (lbs./10^6 Btu)	0.72	0.97	1.50	2.25	3.00	4.50	6.00
C. Percent Removal	90%	90%	90%	90%	90%	90%	90%
Scenario Cost (early 1980 $'s)							
A. Capital ($/kw)	158.50	169.80	178.50	192.80	205.70	221.10	232.00
B. O&M							
-- Fixed ($/Kw-yr.)	8.27	8.67	8.97	9.72	10.57	11.00	11.34
-- Variable (mills/Kwh)	0.12	0.13	0.17	0.24	0.31	0.40	0.50
C. Capacity Penalty	1.29	1.59	1.72	1.92	2.00	2.20	2.47
D. Energy Penalty	1.99	2.62	3.06	3.46	3.59	3.79	3.87

Source: EPA estimates for an existing 500 Mw powerplant. Capital and fixed O&M costs include a 1.3 retrofit factor. For a 250 megawatt powerplant, capital and fixed O&M costs are increased by about 50 percent. For a 100 megawatt powerplant, capital and fixed O&M costs are increased by about 100 percent. Powerplants retrofitting scrubbers are also assumed to incur a reliability penalty of 2.7 percent.

An important assumption affecting the relative costs of scrubbing low versus scrubbing high sulfur coal is that retrofitting dry scrubbers would also require the installation of a baghouse. If existing ESPs (electrostatic precipitators) could be used with dry scrubbers without added costs and technical difficulties, the costs of scrubbing low and medium sulfur coals might be lower.

Lower scrubber costs could result in a reduction in costs under the Cost-Effective Equivalent, and more significantly alter forecasted coal production. Lower scrubber costs will induce powerplants to retrofit more scrubbers and scrub higher sulfur coals rather than switching to lower sulfur coals. High sulfur coal production would likely benefit. Higher scrubber costs would not affect the Cost-Effective Equivalent forecasts because very few scrubbers are forecast to be retrofitted given the scrubber costs employed.

In general, higher assumed scrubber costs would directly increase the costs of the Waxman-Sikorski bill and only indirectly affect the Cost-Effective Equivalent. The result would be an even greater difference in costs between the Cost-Effective Equivalent case and the Waxman-Sikorski bill. Lower assumed scrubber costs would tend to reduce the costs of the Waxman-Sikorski bill more than the Cost-Effective Equivalent, resulting in a narrowing of the cost differences between these two programs.

- **Retrofit Factor** - A 1.3 retrofit factor (applied to capital and fixed O&M of a new scrubber) was used in this analysis to capture on average the difficulties and constraints inherent in retrofitting a scrubber on an existing unscrubbed powerplant. Certain plants and units have considerably higher or lower retrofit scrubbing costs. These variations would have to be addressed in a powerplant specific assessment well beyond the scope of this study.

  Increasing or decreasing the retrofit factor assumed would have a similar effect on forecasted costs and coal production as changes in the level of scrubber costs discussed previously.

- **Removal Efficiencies** - A maximum annual average removal efficiency of 90 percent was assumed for retrofit "wet" scrubbers. Assuming greater scrubber removal capabilities (at a reasonable cost) might result in more reduction under the Waxman-Sikorski bill through scrubbing and less through coal switching. This could in turn result in greater high sulfur coal production. Similarly, more scrubbing and less coal switching might result under the Cost-Effective Equivalent, also enhancing high sulfur coal production. Assuming a lower maximum removal efficiency (such as 85 percent) would lower the amount of reduction occurring through scrubbing under the Waxman-Sikorski bill and increase coal switching. As a consequence less protection for high sulfur coal production would be afforded.

- Scrubber Types Assumed - Conventional limestone "wet" scrubbers and spray dryer "dry" scrubbers were assumed for this analysis. Wet scrubbers are most commonly used, although dry scrubbers are being increasingly used at newer powerplants. Based on the scrubber cost assumptions, wet scrubbers are more cost effective than dry scrubbers to retrofit on existing plants, in light of the assumption that baghouses also had to be installed if dry scrubbers were retrofitted. Further, a 90 percent capital subsidy under the Waxman-Sikorski bill makes more capital intensive scrubbing options attractive (such as wet scrubbers with forced oxidation systems) versus options with higher operating costs (such as dry scrubbers).

  Other scrubber technologies which are utilized less often, such as regenerative scrubbers (e.g., Wellman-Lord or magnesium oxide) were not included in the analysis, because the total costs (capital, O&M and incremental fuel) to retrofit these systems are generally estimated to be higher than retrofitting wet or dry scrubbers. However, the capital intensive nature of regenerative systems may make them relatively attractive when a 90 percent capital subsidy is provided. This could result in higher economic costs under the Waxman-Sikorski bill than forecasted for this analysis.

- New Control Technologies - New sulfur dioxide control technologies were not examined for this analysis. However, given the requirements of the Waxman-Sikorski bill, there is little likelihood that the development of such technologies could reduce the costs of the bill:

  - Sulfur dioxide control technology at each of the fifty highest emitters is required to be installed and operated by the beginning of 1990. This limitation severely constrains the ability of the scrubber industry to manufacture and install conventional scrubbers, let alone develop new control technologies.

- Most new technologies that are promising are generally being developed for new powerplant applications (e.g., fluidized bed combustion, combined cycle gasifiers) rather than for retrofit on existing plants.

- New "retrofit" technologies such as LIMB (Limestone Injected Multistage Burner) can achieve only 50-60 percent reduction, below the 70-90 percent reduction interpreted as being required under the bill. Even if 70-90 percent reduction were not required (but only 70-90 percent reduction below 1980 levels), LIMB may still not be preferred by utilities over conventional scrubbers because a low percentage of LIMB's costs are capital costs. Given the capital subsidy program in the Waxman-Sikorski bill, the more capital intensive wet scrubbing systems would still be preferred.

The Cost-Effective Equivalent case could benefit from new inexpensive control technologies such as LIMB, since reductions are not required until 1995 and 70 to 90 percent reduction is not required. As such, assuming the development of new technologies, could result in an even greater cost advantage associated with the Cost-Effective Equivalent.

RESTRICTING UTILITY AND INDUSTRIAL FORECASTS BETWEEN SCENARIOS

In analyzing the Waxman-Sikorski bill and Cost-Effective Equivalent case, certain activities were held at forecasted base case levels. This was done to facilitate comparison of costs and emissions between scenarios.

- **Gas Consumption** -- was held at base case levels for utilities and industrial sources. To the extent utility and industrial users can shift to more gas, the costs of the Waxman-Sikorski bill and the Cost-Effective Equivalent case to these sectors will be lower due to the lower sulfur dioxide emissions from gas. However, as discussed on page 4-2, the effect of this increase in demand for gas on gas prices could increase national consumer costs substantially.

- **Electricity Transmission** -- was constrained to the interregional flows occuring in the base case. Even if powerpool arrangements or long-term transmission agreements permit changes in these flows, the forecasted costs of the Waxman-Sikorski bill would be only slightly lower. Because most of the reduction under the Waxman-Sikorski bill occurs through forced scrubbing, changes in transmission flows will have little effect on compliance options selected and thus costs. The Cost-Effective Equivalent will also be unaffected because the most cost effective reductions are already being pursued (as a result of interstate trading). Aggregate cost reductions could accrue if additional power could be imported to the U.S. from Canada. The extent to which the Waxman-Sikorski bill, as currently structured, or the Cost-Effective Equivalent might create incentives for greater interregional transmission flows from Canada has not been explored in this analysis.

- **Coal and Nuclear Powerplant Builds** -- were also held to base case levels. Different powerplant builds under the Waxman-Sikorski bill and Cost-Effective Equivalent could affect the forecasted changes in costs, though only slightly. Cost differences could occur if more nuclear powerplants were built in lieu of new coal-fired powerplants in response to the emission reduction requirements. However, given the current concerns surrounding the costs of building nuclear plants, it is viewed as highly unlikely that additional nuclear capacity would be planned in response to emission reduction legislation. This is particularly true given the 1993 deadline imposed by the Waxman-Sikorski bill. This deadline does not afford utilities sufficient time to plan, design, permit, and construct new nuclear facilities.

SITE-SPECIFIC CONSTRAINTS AFFECTING ALTERNATIVE EMISSION REDUCTION STRATEGIES

Site-specific limitations exist which will affect the ability of specific units to pursue certain alternative emission reduction strategies. To the extent possible, a number of these concerns have been captured through specific constraints in ICF's Coal and Electric Utilities Model (CEUM). The forecasted cost and coal production impacts of the Waxman-Sikorski bill are affected most significantly by the retrofit scrubbing costs and other assumptions discussed previously. The cost and production forecasts associated with the Cost-Effective Equivalent are influenced most by the remaining constraints discussed in this section, which primarily influence the cost of switching to lower sulfur coals. The major site-specific issues include:

- **Retrofit Scrubbers** -- As discussed earlier, a factor of 1.3 was applied to the cost of a new scrubber to account for site-specific difficulties in retrofitting scrubbers on an existing powerplant. In addition, costs were increased when scrubbers were retrofitted on smaller powerplants. Also, powerplant units in service for 40 years or more by 1995 were considered too old to retrofit scrubbers.

Mine-Mouth Powerplants -- Mine-mouth powerplants or plants burning only local coals often have limited coal handling and transportation facilities. These limitations are captured to a certain extent in CEUM by requiring some local coal to be supplied to the utility sector. These quantities are relaxed over time so that CEUM is free to substitute non-local coals in increasing proportions, if this is more economic. The costs of upgrading coal handling and transportation facilities have not been included in the cost measures forecast by CEUM.

- **Long-Term Contracts** -- Existing long-term contracts may restrict the flexibility of utilities to switch to different coals under various regulatory alternatives. To the extent that public information on these contracts is available, these contracts were incorporated within CEUM. Similar to the constraints for mine-mouth plants, these are relaxed over time reflecting the known duration of these contracts. In addition, fifty percent of these contracts were assumed to be abrogated, reflecting the exercising of "force majeure" provisions. Aside from these constraints and modelling treatment, no costs were included in this analysis for abrogating existing or newly negotiated long-term coal contracts.

- **Boiler Specifications** -- Certain boiler types (primarily wet cyclones or wet-bottom pulverizers) require the use of low-ash fusion coals. There is a relative scarcity of low-sulfur, low-ash fusion coals, particularly in Appalachia. In an attempt to capture this scarcity, wet-bottom and cyclone boilers were restricted from shifting to very low-sulfur coals. There are a few existing unscrubbed plants with wet-bottom boilers and low sulfur dioxide emission limits. These units were presumed to have obtained sufficient reserves of low-sulfur, low-ash fusion coal to continue to meet their emission limits and were not restricted from using low-sulfur coal.

- **Coal Rank Specifications** -- Existing coal-fired powerplants designed to burn bituminous coals were not permitted to shift to lower rank coals (e.g., from bituminous to subbituminous or lignite). Because of the design of the boilers and particulate removal equipment of these powerplants, burning lower rank coals typically results in capacity deratings, increased forced outage rates, and higher operating costs. At present, little reliable information is available to estimate these costs. Further, these costs are likely to be very site and boiler specific. To avoid these problems, all existing units designed to burn bituminous coals were restricted to bituminous coals when considering shifting coal supplies. To the extent that subbituminous coal compliance options prove to be economic, the increase in regional coal production in the West would be spread among more regions and the cost impacts would decrease.

- **Railroad Pricing Practices** -- ICF uses existing tariffs and real escalation factors reflecting the regulatory effects of the Staggers Rail Act and recent rail deregulation decisions made by the ICC to estimate railroad transportation rates (see Appendix D). For this analysis, as noted in Chapter Two, these rail rate assessments were made in 1982. Individual powerplants may be dependent on certain railroads as sole suppliers. These railroads may in the future be able to establish higher tariffs for specific coal shipments and as a result effectively restrict certain powerplants from shifting coal supplies. Other powerplants may realize lower rates, resulting from competition among different railroads. Such situations were not incorporated in this analysis.

- **Utility System Constraints** -- For any utility, system operating constraints such as area protection and specific unit turn-down rates limit a utility's flexibility to change the operation of its powerplants. Such an assessment could be made through the use of ICF's utility-specific capacity planning and dispatching model. However, the development of such constraints were beyond the scope of this study, and hence, no such constraints were incorporated.

CHANGES IN BASE CASE ASSUMPTIONS

As noted in Chapter Two, EPA used a base case developed at the end of 1982 for this analysis. Since that time, changes have occurred which affect base case specifications and which have been incorporated into a new base case utilized for more recent analyses. Recent changes that could affect the base case forecasts and their effect on the forecasts of the alternative emission reduction cases are discussed below:

- **Railroad Rate Escalation** - In the past year and a half, decisions by the ICC have effectively deregulated railroad prices charged to utilities. It is likely that increasing deregulation of rail movements will lead to increasing competition among railroads. This would be expected to lead to less real escalation or even lower coal transportation rates as railroads price the marginal movements below current tariffs.

Lower rail rates per-ton-mile would be expected to increase the amount of long haul shipments (such as Western coal to Eastern markets) at the expense of shorter haul shipments for local markets. This would probably increase Western coal production at the expense of Midwestern coal production in the base case as new powerplants built in the base case would choose to consume lower sulfur Western coals more often. Further, lower rail rates would reduce the cost of shifting to lower sulfur coals for existing powerplants, resulting in reduced costs for the Cost Effective Equivalent case (in which most of the compliance costs are associated with shifts to lower sulfur coals). The Waxman-Sikorski bill with most of its required reduction forecasted to occur through scrubbing would be much less affected.

- **Electricity Growth Rates** - These would likely be slightly lower than those specified in the current EPA base case. This would lower the utilization of some existing powerplants in the base case, lower base case sulfur dioxide emissions and the required reductions of sulfur dioxide emissions, and thus lower the costs of meeting the targeted emissions levels under the Waxman-Sikorski bill and Cost-Effective Equivalent case.

- **Nuclear Capacity and Generation** - Newer assumptions would be lower reflecting some additional deferrals and cancellations of capacity and lower estimates of the future availability and reliability of nuclear plants. Less nuclear generation would result in increased utilization of existing powerplants and more new coal powerplants built. Although base case emission forecasts would be higher, required reductions would not increase since emission increases above 1980 levels from new plants and increased utilization of existing plants are exempted under the Waxman-Sikorksi bill.

- **World Oil Prices and Gas Prices** - Lower world oil prices would be forecasted than assumed in the current EPA base case, reflecting OPEC's recent price reductions and a revised assessment of future market conditions. Lower oil prices would also mean lower gas prices (after deregulation of gas). Lower oil and gas prices would be expected to reduce the demand for coal at smaller existing industrial boilers and at new industrial facilities. To a lesser extent, lower oil and gas prices would slow the replacement of existing oil steam powerplants with new coal fired powerplants (i.e., accelerated replacement) particularly in the Gulf states. These changes would affect sulfur dioxide emissions from existing sources only slightly and therefore have relatively little impact on the cost and coal production impacts of the Waxman-Sikorski bill and Cost Effective Equivalent.

- **Lower High Sulfur Coal Production** - For some of the reasons noted above and due to structural changes and recent data refinements in the ICF Coal and Electric Utilities Model, Midwestern coal production is forecasted to be lower in the new base case by 1995, than in the base case forecasts used in this analysis. Hence, for this new base case mining employment levels in 1995 relative to 1980 levels would also be lower. As such, proposals which result in a significant amount of coal switching such as the Cost-Effective Equivalent could result in mining employment being reduced below 1980 levels in more of the high sulfur coal producing regions than indicated in this analysis.

OTHER CAVEATS AND UNCERTAINTIES

Additional caveats and uncertainties specific to this analysis are discussed below:

- **Emissions and Emission Reductions in Other Sectors** -- The sulfur dioxide emissions and emission reductions forecasted for this analysis were assumed to come from the utility and industrial sectors (i.e., industrial boiler and process heat applications). These emissions are estimated to be about 80 percent of total emissions in 1980. Emission reductions from the other sectors and sources are also available but in general are not cost-effective. However, reductions from copper smelters in the West could be cost-effective. The allocation scheme specified under the Waxman-Sikorski bill results in relatively few required reductions in the West, particularly in the states with copper smelters. Thus, assuming cost-effective reductions from copper smelters would displace only a few more costly utility emission reductions. Therefore, the total costs of the Waxman-Sikorski bill forecasted in this analysis would not be reduced appreciably. However, permitting interstate trades across the U.S. could enhance the value of the smelter reductions and reduce costs more under the Cost-Effective Equivalent case.

- **Offsetting Emission Increases in Other Sectors** -- Under the Waxman-Sikorski bill, credits and exclusions were provided for gross emission increases from existing utility and industrial sources. For sources other than utility and industrial sources, it was assumed that emissions from existing sources would be at 1980 levels in 1995. To the extent fuel switching or increased utilization results in higher emissions at these sources, overall reductions forecasted for the Waxman-Sikorski bill may be lower than indicated in this analysis.

The **Chairman**. I have no further questions of the panel at this time.

Any other questions?

Senator **Ford**. No.

The **Chairman**. Gentlemen, thank you very much for your testimony.

Senator **Ford**. Mr. Chairman, I wish to submit my question to Mr. Hill in writing.

Mr. **Hill**. OK, Senator.

The **Chairman**. Thank you, gentlemen.

[Subsequent to the hearings, the following questions were submitted to Administrator Ruckelshaus, Secretary Hodel, and Chairman Hill; the answers appear in appendixes C, D, and E, respectively.]

JAMES A. McCLURE, IDAHO, CHAIRMAN
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United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

The Honorable William D. Ruckelshaus
Administrator
Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Administrator Ruckelshaus:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Administrator William D. Ruckelshaus by the Committee on Energy and Natural Resources

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

1. What is the scientific consensus on the natural pH of rain? Are there any studies which claim the natural pH of rain is from 3.6 pH to pH 5?

2. Have any scientific theories been advanced which indicate that acid deposition is not due to SO_2 or NO_x emissions from manmade sources, but rather to things like the acids in soils, or other factors such as non-chemical factors? If there are such theories are they generally accepted in the scientific community?

3. Is there any direct link between emissions of SO_2 and damage to human health, crops, soils, forests or surface waters? What do we know about the status of the science in these areas, and what research needs to be done before we have answers upon which policy decisions might be made? What are the scientific uncertainties?

4. Do we know how much damage has occurred that is attributable to acid deposition and the rate at which it is occurring?

5. How do cations influence acidity levels?

6. Is there any scientific evidence showing sulfate levels are reducing over time in any particular region of the country? What do we know about trends of acid deposition and the rates at which it is occurring?

7. Is there any scientific consensus on the relative contribution of long range transport of acid deposition as compared to that of local sources? What is the relevance of knowing the answer to this question in instituting an acid rain control program?

8. Is acid deposition getting worse over time in any particular region of the nation?

9. What were the findings of the Hubbard Brook Study?

10. Is there any scientific evidence to show a relationship between SO_2 and NO_x and other aerosol concentrations in the atmosphere? What is the relevance of any relationship between these elements in terms of efforts to institute an acid rain emissions control rollback program in this country?

11. Is there any scientific evidence to indicate the natural acidity of the soils is really causing acidity in the water reaching lakes in the Adirondacks?

12. Is there any scientific consensus on the contribution of natural SO_2 deposition as compared to man made sources? What estimates are there, if any?

Questions Submitted to Administrator Ruckelshaus (continued)

13. How many lakes are there in acid deposition sensitive regions of the Northeast? Of these, how many are acidic and incapable of sustaining aquatic life? Of the acidic lakes, can they be biologically revived by liming, and if so, at what cost?

14. How many lakes in the Eastern U.S. are not threatened by acid deposition due to a high buffering capacity of the soil?

15. What is the average size of the acidic lakes in the Northeast as compared to those which are not acidic?

16. What do we know about the rates of change in the chemistry of lakes and streams, or biota or fish as a direct result of acid deposition?

17. Do we know whether or not acidification is at a fixed point in acid deposition sensitive areas, or whether it will the aquatic and terrestrial ecosystems will continue to degrade at a rapid rate? Are there any alternative scientific theories on this point? If so, how are they relevant to whether or not an acid rain control program must be instituted at this time?

18. Are the concentrations of either SO_2 or NO_x emissions relevant to curbing the amount of acid deposition which falls in a particularly sensitive region of the country such as the Adirondacks?

19. What is the relationship between sulfate deposition and trends for SO and NO_x? Is this relevant to the debate on the linearity - non-linearity debate between the National Academy of Science and the National Labs? What is the relevance for these two theories on an acid rain control program of 10M tons rollback in SO_2 emissions in the Midwest?

20. Is the status of the acid rain research such that we know whether or not and in what way acid deposition is contributing to the decline of forest growth?

21. Is there any evidence to support a theory of combined pollutant effects on foliage rather than through soil processes in the root zone? What does the difference mean in terms of SO_2 emission controls from long range as opposed to short range sources from man mande emissions?

22. Is there any direct scientific evidence linking acid deposition to forest damage? What about scientific studies which indicate the cause of tree damage to German forests is directly caused by ozone attack on the needles, possibly in combination with SO_2, NO_x, or both? What studies suggest that more than one mechanism could be contributing to the cause of tree damage?

23. Is damage from acid deposition being experienced in parts of the United States other than the Northeast, as is suggested by the recent National Wildlife Federation Report? Do you agree with the conclusions reached in this report? If not, why not? Is there scientific consensus to support the conclusions reached in the study?

Questions Submitted to Administrator Ruckelshaus (continued)

24. What do we know about the causes and effects of acid deposition, and where is the science yet uncertain? When might we have some answers to the areas of scientific uncertainty, and how will the answers to these issue areas affect our ability to deal with the problem of acid deposition?

25. What is the temporal and spatial distribution of acid deposition?

26. What are the latest studies of soils as they relate to acid deposition and tree damage, and what are the various theories of how acids are transported through pathways in the soil to lakes and tree roots? Does the soil itself, and the level of its acidity or buffering capacity make a difference in whether or not tree roots are damaged or lakes become acidic?

27. If a 10 million ton SO_2 rollback program were instituted today under the following varying scenarios, do we know whether acid deposition would be proportionately reduced in the acid sensitive Northeastern U.S.? What are the cost estimates for the controls under these varying scenarios, including, in addition to things like compliance costs for scrubbers, coal switching, increased electric generating consumer costs, and energy impact, associated job losses? Can we measure the benefits of the rollback?

    a) S. 768
    b) H.R. 3400
    c) H.R. 4404

28. The present regulatory climate seems to encourage the use of existing coal-burning plants far beyond their normal life expectancy. Should we be providing incentives to spur the retirement of these older plants and encourage the construction of new plants with more current emission control devices?

29. When would the present Clean Air Act provisions achieve through plant retirements and other actions the same reductions in sulfur dioxide emissions that are being mandated by the Senate Environment and Public Works Committee?

30. What progress has been made over the past decade in reducing sulfur dioxide emissions in the Northeast, Midwest, South and West?

31. Don't several recent studies, including the National Academy of Sciences 1983 Report and the Interagency Task Force's FY'82 report, suggest that local emissions from petroleum and coal combustion may contribute just as significantly to the occurrences of acid deposition as do emissions from long-range sources?

JAMES A. McCLURE, IDAHO, CHAIRMAN

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United States Senate

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

The Honorable Donald Paul Hodel
Secretary
Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Mr. Secretary:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Secretary Donald Paul Hodel
by the Committee on Energy and Natural Resources

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

1. What is the Deparment of Energy doing to develop new clean coal-burning technologies, including providing either federal research or federal assistance towards research for the commercialization of emerging sulfur dioxide control technologies? How much money is being spent on these efforts in the Department of Energy budget and how much is provided in the proposed federal acid precipitation research effort for BY 1985?

2. If an acid rain control program is adopted now which requires scrubbers, what coal supply regions of the country would stand to lose markets due to coal switching? What energy losses would there be? How many coal mining jobs would be affected? What would the costs be? Please answer these questions as they pertain to the controls proposed by: (a) S. 768; (b) H.R. 3400; (c) H.R. 4404. If any studies have been done examining these issues, would you please submit them for the record.

3. How much scrubber capacity can be retrofitted in this country by 1990?

4. What, if any, difficulties are there with backfitting the installation of flue gas cleaning facilities for sulfur dioxide removal at existing power plants? Have any studies been done on this subject? If so, would you please submit them for the record.

5. Are there any waste management problems associated with the installation of scrubbers on fossil fuel fired plants? If so, what are they? Is groundwater affected, and if so, how?

6. Where are we now in terms of achievable technology with regard to technology on scrubber options and new developing technologies. How do the costs for new technologies compare with present scrubber technology and when might these newer, cost efficient technologies be available for the marketplace?

7. What is the remaining lifetime on the largest emitters of sulfur dioxide? (Answer this in terms of the 50 largest emitters in the nation]

8. What are the sulfur dioxide emission densities in the West as compared to those in the East? How much of the coal fired generation in the West is scrubbed?

Questions Submitted to Secretary Hodel (continued)

9. What is the average sulfur content of the coal burned in the East as compared to that in the West?

10. How much in dollar terms is spent on environmental controls at a new plant? Are there any dollar averages for retrofitting an existing plant?

11. What would the total costs of S. 768, H.R. 3400, and H.R. 4404 be? What if any benefits would there be from these expenditures? Could these costs be translated into dollars per pounds of fish saved in the Adirondacks?

12. Is there any relationship between net imports of power from Canada as an alternative to retrofitting scrubbers on American utilities if acid rain controls are imposed at this time? Do long-term bulk power imports from Canada constitute an attractive alternative to coal fired generators for capacity additions in the late 1980's and 1990's, despite coal's continuing economic advantage?

    o Would electric rates be any higher under imported power than if coal based?

    o How much power is Canada importing into this country? How much of an increase is this from 1981?

    o Is is possible that increased purchases of power from Canada might displace the construction of new U.S generating capacity?

13. How might an acid rain control program as envisoned by S. 768 or H.R. 3400 result in this nation's increased dependence on imported power from Canada? What would this reliance mean in terms of our policy of energy independence? In terms of lost domestic energy capacity?

14. The Ad Hoc Committee to Review the National Acid Precipitation Assessment Program (NAPAP) filed its report in December, 1983. The report included this recommendation at page 12:

> "The Federal funding level for development and demonstration of new control technology should be increased substantially to complement on-going industry commitments. The development of new and improved, retrofittable, emission control technologies followed by successful pilot- and demonstration-scale testing, is of key importance in the potential long-term mitigation of acid deposition."

What was the reaction of the OMB and the Administration in general to this recommendation?

JAMES A. McCLURE, IDAHO, CHAIRMAN

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LOWELL P. WEICKER, JR., CONN.
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MALCOLM WALLOP, WYO.
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United States Senate

COMMITTEE ON
ENERGY AND NATURAL RESOURCES

WASHINGTON, D.C. 20510

May 10, 1984

The Honorable A. Alan Hill
Chairman
Council on Environmental Quality
722 Jackson Place
Washington, D.C. 20006

Dear Chairman Hill:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Chairman Alan Hill
by the Committee on Energy and Natural Resources

on behalf of Senator Ford

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

Mr. Hill, your August 19, 1982, testimony before this Committee contains the following statement:

> Although acid rain is blamed for a variety of ills, actual causes and effects of the phenomenon are not fully understood. In my view we must address three questions before we can begin to consider an emissions control strategy in legislation. First, we must ask how well we understand atmospheric chemistry and the long-range transport, ultimate deposition, and ecological effects of acid rain. Second, we must determine whether there is a relationship between natural and manmade influences on the development of acid rain. Finally, we must determine how particular strategies to control emissions will affect the amount of acid rain generated and its effects on the ecosystem. At this time we cannot answer any of these questions satisfactorily.

Mr. Hill, can we answer any, or all, of these questions satisfactorily at this time?

The CHAIRMAN. We have heard two panels, and we have six. It would be my intention to hear one more panel and then recess until this afternoon. And I think that meets the desires of most members of the committee.

I'd like to then call members of panel No. 3, Dr. Christopher Bernabo, Dr. Raphael Kasper, and Dr. Bernard Manowitz.

Dr. Bernabo, you're No. 1. If you would lead off. Your entire prepared statement will be placed in the record in full, and you're invited to summarize it in whatever way you would prefer.

STATEMENT OF DR. J. CHRISTOPHER BERNABO, EXECUTIVE DIRECTOR, NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

Dr. BERNABO. Thank you, Mr. Chairman.

I'm very pleased to be here today to discuss the statutory National Acid Precipitation Assessment Program.

This program, as you know, has been mentioned today, grew out of the Energy Security Act. The goal of the program is to develop and progressively improve the objective and comprehensive information base for use by decisionmakers.

Now, in establishing the program in late 1980, the Congress recognized both the urgency of the issue, and the long-term need for research to address it adequately.

The program includes research monitoring assessment activities, and it was given a 10-year renewable mandate, with annual reporting duties.

I want to point out that there was a statement made here earlier, I think erroneously, by Senator Byrd, that there's going to be some final report. This is an ongoing program, with annual reporting requirements. And, indeed, it has been mentioned that we will soon be releasing our annual report for 1983 to the Congress.

Now, 1983 was the second full year of research. We began in 1982. There's been a shift in our emphasis as the seeds we have planted, so to speak, have bloomed, and we're in the process now of focusing more research on the key questions and on the output of results.

The program includes 12 Federal agencies. Again, as I have mentioned, it's a very broad program, because of involving the various producers and users of information.

One of these that we have done in recent years, a very important program, is an objective policy neutral effort, a scientific effort, not a policy-development effort, and, indeed, we have major peer reviews of all the projects within this program, public reviews of over 275 projects.

We have had workshops and meetings that brought the producers and users of information, the scientists, and decisionmakers, including Hill staff and others, together to discuss both the availability of information and what it means, what research can do and, indeed, the limitations to research.

Now, in developing the program, again I think it's important to mention that the Congress established it with cochairing by the National Oceanic and Atmospheric Administration, Environmental Protection Agency, and the U.S. Department of Agriculture, but includes a whole host—and you can see on page 2 of my testimony of other groups.

And also we have, of course, Dr. Manowitz here from the National Laboratory Consortium for national laboratories and for Presidental points. These are also included. And these national laboratories perform acid rain work for the task force under the national program. He will be describing that.

The task force itself functions sort of as a board of directors; sets the goals and so forth for the program. I have listed there a number of its responsibilities in producing annual reports.

We have interagency budget processes I would like to explain a little bit. It's very important, I think, that the Federal effort is well coordinated with the efforts of other groups.

There are major efforts. The State of California, for instance, has a $4-million-a-year acid rain program going on. Private sector groups, such as the Electric Power Research Institute, that we'll be hearing from a little later, with about a $15 million effort.

There are major peer review, open research efforts out there which we work with very closely to coordinate.

Also, obviously important is that we inventory the various work going on so that the people can find out what is happening throughout the Federal Government from a single source, and also disseminate these results to the various users.

Now, at page 16, you will see a diagram of the various task groups. We have 10 technical task groups. Some of the major activities of those task groups are listed, and the agencies responsible for overseeing them.

I think the role of the task force in planning the interagency budget is a rather unique aspect of the program.

By working together through the task force, the agencies have established a research program that addresses national needs, while building other research expertise of the agencies.

The strong interagency planning process ensures an integrated and comprehensive rather than piecemeal approach to the issue, and it helps avoid unnecessary duplication and crucial gaps.

And again, on pages 17, 18, and 19, you can see a history of the funding for the program beginning in 1982, and also the budget tables for 1984, the current fiscal year, and the proposed budget of 1985, which is now before the Hill for consideration.

Now, despite this integrated budget processing, one of the problems is, of course, when this budget comes up to the Hill, it is split up into the various jurisdictions of committees. I would just like to point out again, the planning of this effort was in fact integrated, and to keep that in mind in looking at the various portions of the budget as they come to the various appropriate committees in Congress.

Now, our annual report which is soon to be released. I'd like to spend the rest of my time just giving some highlights, which is most of what the rest of my testimony is, on some of the issues that come up in that.

We are again describing during 1983, the progress in the second year of research, and also some information on the state of the science as it is evolving from one year to the next.

Now, the acid rain debate has steadily intensified, as you're well aware. This has increased the demands for authoritative information, while also heightening emotionalism surrounding the issue.

The national program is addressing these urgent demands for information, while maintaining its essential objectivity, which is crucial to our scientific mandate.

The demands of providing best guesses based on current information must be balanced against the need to perform only technical, defensible analyses, and avoid conjecture.

There has already been some discussion—as I go into talking about the science—about this National Academy study and the state of information on the relationship between emissions and deposition. The two gentlemen on either side of me are more qualified than I, as I haven't been involved in that.

But let me say that I think the controversy is somewhat of an artificial one; that, in fact, there is quite a bit of agreement between the groups. It's a matter of what time and space scale you're looking at in the relation of deposition and emission, not whether or not they're related in the manner described. So let me pass over that.

I think it's important also to note that current atmospheric models do have a certain amount of uncertainty in them, up to tenfold. This is a problem particularly because we very often lack the real-world data, if you will, to validate these models to determine their usefulness in policy analysis and so forth.

We are, in fact, developing not only a new generation of models which will help improve the predictions, but also planning large-scale field studies in order to get the information that we need.

Now, clearly there is a scientific consensus that man-made emissions have increased the acidity of precipitation in eastern North

America, and that, in fact, 90 percent-plus of the acidity in that region is from manmade sources.

However, there is also a consensus, as I think you have heard today from other witnesses, that we do not know what the pattern or trends have been over the past years. We just did not have the monitoring and other data.

There have been some assertions in the past largely now—the question. And, indeed, the National Academy of Sciences has, with us, as well as others sponsoring it, concerted efforts with a blue ribbon panel to look at all the evidence we have, not only in precipitation, but lakes and so forth, into the past to have some sense of what can we say about trends, has the problem been getting worse and at what rate?

As Administrator Ruckelshaus pointed out, I think a key question is the rate at which change is taking place.

There is a consensus now among the scientists, we don't know what that is, also a consensus that it's something that we need to know.

In terms of effects of deposition, there's no question that certain lakes have been affected, and fisheries loss has taken place.

Again, the problem here is we do not know the extent of those damages, nor the rate. And as Mr. Ruckelshaus and others have mentioned, we have under the program a large effort to go out this summer—fall, actually, and examine a whole series of lakes, get a better feeling of what the size of the resource is at risk.

We have similar efforts in materials. We're inventorying throughout the Northeastern United States all the materials which may be sensitive to acid deposition. And we're beginning to develop the concept of how we can go inventory the terrestrial resources, forest and soil. There's still some controversy as to how you would do that, but determine again the size of the resource at risk.

I think one of the things that we can point to that is very important is that watersheds do vary quite a bit in how they respond. There's no simple model or formula for how they're going to be affected. And, indeed, a lot of work is going into that area.

In the area of terrestrial effects, again, we have heard a lot about the forests. And, indeed, the research program—not only ours, but others—have tended to decrease our concern about crops, while increasing them about forests.

There is no doubt that there are signs of environmental stress in forests of North American and Europe. Again, the quarrel as to the source of this is a subject of lively scientific debate not only here, but in Europe, as you have heard.

These growth reductions again have been seen not only in the northeastern, but also down to the southern region into North Carolina and Tennessee.

I'd like to just quickly say something about the evidence, where the state of evidence on this information is.

Declines do appear to be most severe in the regions with the highest levels of acid deposition ozone and SO_2. All those pollutants are concentrated in those regions.

They come about, they are manifest about in the last 20 to 30 years when regional scale pollution was increasing. They do not show a consistent association with drought or other known natural factors as causitive.

But we do not understand the mechanisms by which either of these various pollutants interact. And, again, it may well be a set of complex causes, not only acid deposition, but gaseous pollutants and natural causes. We're trying to sort that out, and working very effectively with our colleagues in Canada and Germany with a similar problem.

Now, in addressing the acid rain issue, I think it's important to understand—I think as Senator Mitchell and others who are in favor of action, also pointed out, that it's going to require both research and appropriate environmental policies to address the issue.

Science can certainly provide good objective information on what the level of certainty or uncertainty is, what's known and isn't known. But many of the key decisions, as you're well aware, involve major value judgments on who pays and so forth. And those are areas where science can be a very limited help.

But, indeed, the science is moving us forward in the way of being able to more competently determine which actions will have the best environmental results, given the proposed actions.

Now, in the program, from page 8 to 12, there's a series of highlights of specific things which have been accomplished. Let me just go over some of those briefly, and leave to the record the more detailed analysis.

In terms of manmade sources, we are improving the inventories, the available information on what types of emissions are taking place. We're developing a model, the advanced utility simulation model, which will help us in regional forecasts as well as larger ones on the cost in emission changes from different proposed strategies.

So tools for implementing various approaches are there.

We have conducted the cross-Appalachian tracer experiments, so-called CAPT experiment. I might point out that this was done jointly with Canada as well as with support from the Electric Power Research Institute. This is a major experiment, where we track clouds of inert gas from releases in Dayton, OH, a major source region, I would say, and also Sudbury, ON.

And, indeed, the results of that analysis are now being analyzed. It will be used to verify and further increase our understanding of long-range transport.

As was pointed out before though, there is still a large controversy as to the role of local versus long-distance transport, and we have a number of studies addressing that.

We have been establishing prototype, if you will, dry deposition research sites, because also, as you might be aware from previous testimony, dry deposition is a very important part of the total influx of acids, and yet we don't even yet have a means of measuring it.

In the wet deposition area, the national trends network, that has been referred to several times, is now at a strength of 150 sites, I believe. We installed 17 new sites last year to increase the special coverage in key areas throughout the country.

It has also been pointed out, acid deposition is not just an eastern issue, this is a nationwide network and we're concerned about increasing some of the coverage in the Western States, where concern is growing.

In the aquatic area, we have completed an inventory of existing water quality data, and examined the extent and degree of sensitivity; maps, which you may have seen, which have been widely published, showing the areas of sensitivity.

We have established long-term monitoring so that we can look at areas and see over time what changes are occurring.

We have also looked at drinking water in the Northeast for the possibility of mobilization of heavy metals and so forth, and determined that while some of the waters are, indeed, corrosive, that the levels of metals do not exceed the EPA maximums at this time. We are continuing study on that issue.

We have initiated a major study of forest productivity in the Eastern United States. And some of the results of that and other studies you have heard about.

We have numerous studies on the effect on seedlings and various trees, so far indicating no effect in the laboratory above a pH 3.6 for the ones that have been tested.

The CHAIRMAN. Could I interrupt at that point.?

Dr. BERNABO. Yes.

The CHAIRMAN. You say you indicate no effects at or about pH 3.6. What is the acid rain level measured in the airsheds where we're seeing adverse effects——

Dr. BERNABO. Well, in general—well, again—it varies from event to event, but on an annual average basis it's something like 4.2 in the——

The CHAIRMAN. It would be above the level that is shown here?

Dr. BERNABO. That's correct.

The CHAIRMAN. Thank you.

Dr. BERNABO. Now, that can be misleading though, because trees which are on sites, let's say mountaintop sites, where they are continually in the clouds, may be exposed to a lower pH. But in terms of the rainfall itself, the precipitation we're talking about, it's 4.2.

The CHAIRMAN. Thank you.

Dr. BERNABO. We are also again looking at crops. The studies to date have indicated decreased yield in some, and minor variations. The border ones we have looked at do not show decreases, but we have far from done enough analyses to really say definitively about crops.

Materials is clearly a big concern. Clearly, acidity affects the rate at which materials corrode and erode. The question is, how is it related to other pollutants and natural forces which cause these effects as well?

And we're establishing field sites in a variety of conditions with exposure of different materials. And, as I mentioned, we're inventorying the building materials and cultural resources in the Northeast. After 1985, we will in fact do that nationwide.

Control technologies we do not fund directly under this program, control technology development. But I have listed here some of the key developments that have taken place in the other related efforts.

In the assessment area, we have had reference already to the critical assessment review papers. This was a set of documents done by 52 leading experts in the world that are bringing together one document, a summary of what we know and don't know about acid rain. It's sort of a benchmark from which our scientific progress could be measured.

We're also developing techniques. One of the problems that we face in acid rain is we are pioneering. We're moving forward, not only basic science, but the techniques applying science to understanding its interactions. And, indeed, we are working with the National Laboratory Consortium, Carnegie Mellon University and others, different groups, looking at methodologies for assessing these various costs and benefits, and how they can be applied to help decisionmakers.

An important aspect to the acid rain issue again, I'm sure as the committee is aware, is the international aspect. And although, as I'm sure again, as most people are aware, we have quite a few disagreements with our neighbors to the north about policy.

In fact, in research we have cooperated very closely with the Canadians. They sponsor roughly $20 million a year in research. And we have met at an annual or more frequent basis with their equivalent of the task force, the Research Monitoring Coordinating Committee. Last year we expanded bilateral cooperation to include 12 new joint U.S.-Canadian projects. We will be meeting with them again, I believe it's next week, to look out into the future.

We also jointly sponsored in Quebec City an International Conference on Forest Damage between the United States and the Canadian Forest Service and brought together experts from around the world on this important subject.

We're now meeting more frequently than we have in the past, but in a more formalized way, with the scientists and government people from the Federal Republic of Germany.

We now have an exchange of scientists set up to send forest researchers from Germany here to examine our situation and vice versa, and also setting up plans to look at dry deposition techniques in other areas.

There's a lot of fruitful research interaction occurring there, as the Germans develop a more advanced, more accelerated research program which they're embarking on at this time, particularly given their concerns about the forests.

Let me also go over some of the other areas that I have some more detail in there, but do——

The **Chairman**. I wonder if I might interrupt at this point. Your entire statement will go in the record. Taking your time to read it is not necessarily constructive.

Mr. **Bernabo**. I agree. Let me conclude.

The research and monitoring activities of the program are designed to successfully provide better tools from improving information base, both for developing and implementing sound policies.

And I think again that the important thing here is that we're moving forward on a broad front. The funding has been increased, the program and efforts have been accelerated, and we do indeed have plans, detailed plans for gathering the information as we go out into the future.

And many outputs have already been put out, as described in the annual report and our upcoming ones. I think given the acceleration of research, not only under the Federal aegis but also by the private sector, States and others, considerable new information of acid deposition will be available for decisionmakers in the time to come.

Thank you.

[The prepared statement of Dr. Bernabo follows:]

STATEMENT OF

DR. J. CHRISTOPHER BERNABO
EXECUTIVE DIRECTOR
NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

30 April 1984

Mr. Chairman and other members of the Committee:

It is a pleasure to be here to describe the progress of the statutory National Acid Precipitation Assessment Program (NAPAP). I serve in an interagency capacity as the Executive Director of the National Program, while on assignment from the National Oceanic and Atmospheric Administration (NOAA).

The goal of the National Acid Precipitation Assessment Program is to develop and progressively improve on an objective and comprehensive information base for use by decisionmakers. In establishing the National Program in late 1980, the Congress recognized both the urgency of the issue and the long-term need for research to address it adequately. The statutory program, which includes research, monitoring and assessment activities, was given a 10-year renewable mandate with annual reporting duties. The need to bring together the many important producers and users of acid deposition information was also recognized, with 12 Federal entities united to work together in an integrated effort. This unique long-term and broad-based approach was recognized as essential in order to tackle effectively the great complexity of the acid precipitation issue.

In 1983, the second full year of research under the National Program, our activities entered a new phase. During 1981 and 1982 emphasis was on planning and organizing the comprehensive program. Now work is well underway and the emphasis is shifting toward producing results and working with the users of the information. Major peer reviews of all the work -- over 275 projects -- have been held. National meetings and workshops have brought the producers and users of acid deposition information together. Great strides have been made in building and focusing the comprehensive program on the key scientific questions relevant to decisionmakers' needs. A continuing dialogue has been established to provide feedback between users and producers of information -- decisionmakers and scientists -- so that the work remains useful, and the strengths as well as limitations of the planned research are better understood.

Information on acid deposition has many different and important uses, and the National Program thus has a diverse clientele. Primary emphasis is on meeting the needs of decisionmakers in the Congress and Executive Branch who are concerned with developing sound environmental policies for the Nation. Most attention in the public debate has been focused on information relevant to determining regulatory policy about sulfur dioxide and, to a lesser degree, nitrogen oxide emissions.

There are many other uses of the information beyond the debate on emissions control policies. Acid deposition information is needed by resource managers responsible for stewardship of lakes, forests, crops, wildlife, and cultural monuments; by Federal and private sector managers of energy resources; and by public, environmental, professional, and trade organizations in formulating their positions and activities. Decisions for which acid-deposition-related information is valuable are made daily in these many areas, and the National Program is dedicated to providing better information for each of them.

LEGISLATION AND ORGANIZATION

The Interagency Task Force on Acid Precipitation was established under the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act - P.L. 96-294) to oversee the planning and implementation of the National Acid Precipitation Assessment Program. The Task Force is jointly chaired by the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and the Department of Agriculture (USDA). The remaining members include: the Departments of Energy (DOE), Interior (DOI), Commerce (DOC), Health and Human Services (HHS), and State (DOS); the Council on Environmental Quality (CEQ); the National Aeronautics and Space Administration (NASA); the National Science Foundation (NSF); and the Tennessee Valley Authority (TVA). The Task Force also includes the directors of Argonne, Brookhaven, Oak Ridge and Pacific Northwest National Laboratories, as well as four Presidential appointees. NOAA has a statutory leadership role to "direct the research" and provides the National Program's Executive Director.

The Task Force itself functions as the board of directors for the National Program by setting the research goals, identifying the projects needed to meet these goals, and deciding which agencies are best suited to conduct the necessary work.

The primary responsibilities of the Task Force are to:

- Plan and manage the National Acid Precipitation Assessment Program.
- Provide annual reports on the National Program's progress.
- Produce an annual interagency budget for the National Program.
- Coordinate the National Program with the research and monitoring activities of the private sector groups, environmental organizations, states, and other nations.
- Maintain an inventory of Federally-funded acid deposition research projects.
- Develop and update the National Program's Operating Research Plan.
- Ensure that research projects are technically sound and credible with periodic peer reviews by the scientific community.
- Disseminate research results.

The Task Force has 10 working-level Task Groups, one for each of the National Program's nine research categories and one for international activities. These technical groups include program managers and experts from all the participating Federal agencies and National Laboratories. They are responsible for the detailed planning and research in their assigned areas. The Task Groups with their Coordinating Agencies are:

A. Natural Sources (NOAA)	F. Terrestrial Effects (USDA)
B. Man-made Sources (DOE)	G. Effects on Materials (DOI)
C. Atmospheric Processes (NOAA)	H. Control Technologies (EPA)
D. Deposition Monitoring (DOI)	I. Assessments (EPA)
E. Aquatic Effects (EPA)	J. International Activities (DOS)

Figure 1 shows the major activities of the ten Task Groups.

Funding History and Budget Process

The Task Force's efforts in planning and managing the National Program were built upon previous Federal activities. Prior to the passage of the Acid Precipitation Act of 1980, several Federal agencies were sponsoring acid rain research, but in a piecemeal fashion rather than as a coordinated program. The Acid Rain Coordinating Committee (ARCC), which was established in 1980, was an attempt to organize the ongoing Federal efforts. After the Act passed, the ARCC was reconstituted, and provided the foundation upon which the statutory National Acid Precipitation Assessment Program was established. The Task Force developed its first interagency budget for the Program in January 1981, and submitted it to Congress as part of the President's FY 1982 budget request.

The role of the Task Force in planning the interagency budget for the National Program is a highly effective and unique aspect of the Federal effort. By working together on the Task Force, the agencies have established a research program that addresses national needs while building on the research expertise of the individual agencies. This strong interagency planning process ensures an integrated and comprehensive program that avoids unnecessary duplication or crucial gaps in the overall national effort.

The Task Force is vigorously implementing this comprehensive national research program. The history of Federal funding for acid deposition research from FY 1982 to FY 1985 is illustrated in Figure 2. The interagency budget for the National Program was $17.4 million in FY 1982, and $22.3 million in FY 1983. Funding in FY 1984 is expected to be about $33 million, which includes a base of $27.5 million (Table 1) and a proposed supplemental of $5.5 million for a national lakes survey. In FY 1985, the President has requested $55.5 million for the National Program (Table 2). This increased funding for the National Program will accelerate the rate at which scientific uncertainties are narrowed so that the pressing policy questions can be addressed more adequately. Information is being produced at an increasing rate as the ongoing research yields results, but we cannot mandate answers - they must flow from careful scientific work.

Annual Report

By law the Task Force is required to issue an annual report to the President and Congress describing the progress of the National Program. Our third Annual Report, which will be issued in June, summarizes the major scientific issues that were addressed by the National Program in FY 1983, the progress of researchers in reducing the uncertainties of assessing the causes, effects, and management of acid deposition. This report emphasizes major research findings that will provide better information for legislators, regulatory officials, resource managers, private sector decision makers, and the public to deal with the acid deposition issue.

In the remainder of my statement I will summarize some of the highlights of the upcoming Annual Report to the President and Congress.

STATE OF THE KNOWLEDGE

The acid rain debate has steadily intensified, causing increased demands for authoritative information and heightening the emotionalism surrounding the issue. The National Program is addressing these urgent demands for information while maintaining its essential objectivity which is central to its scientifically-oriented, policy-neutral mandate. The demands for providing "best guesses" based on current information must be balanced against the need to perform only technically defensible analyses and to avoid conjecture. There are increasing pressures because many scientific uncertainties remain while the demands for definitive answers mount. However, the value of the National Program is no greater than its scientific credibility, and that must be maintained by rigorous technical analysis and adequate peer reviews.

Our understanding of the acid deposition phenomenon is rapidly evolving as research yields new results and old data are re-analyzed in light of new information. Some highlights of the changing state of scientific knowledge are briefly described here.

Relationship between Emissions and Deposition

The precise relationships between emissions and deposition are still unknown, with existing atmospheric models having uncertainties in their predictions of up to 10 fold. However, based on the limited information available, it has been suggested that when averaged over the entire eastern half of North America for a year or more, there appears to be a nearly one-to-one (linear) relationship between emissions and deposition. Over smaller time and space scales though, this relationship may not be a one-to-one relationship. For instance, a 50 percent reduction in SO_2 emissions in eastern North America may result in an overall average 50 percent decrease in the deposition of sulfur compounds, but the actual change will vary from place to place so that a specific sensitive region or state may not experience a commensurate decrease in the deposition of sulfur compounds. Extensive research is being done by the National Program to improve our ability to predict more accurately the relationship between emissions and deposition.

The results of laboratory studies are improving our understanding of chemical reaction rates and pathways of pollutants emitted into the atmosphere, and of the products of these reactions. Mathematical simulation models provide a basis for integrating and interpreting the research studies on atmospheric transport, chemical and physical transformation, and removal, and for quantifying source/receptor relationships. With advances in scientific research and in computer technology, the field is now ripe for rapid progress.

A key assessment and policy analysis tool will be a new generation of atmospheric models, such as the Eulerian Regional Acid Deposition Model being developed at the National Center for Atmospheric Research. But theoretical models by themselves cannot provide the necessary scientific credibility in determining source/receptor relationships. The models' predictions must be evaluated by comparing their results with actual observations. The National Program is thus planning to conduct large-scale field studies to provide the data that are needed to confirm model assumptions and model characteristics. In the past, the lack of model verification has been a key factor in the scientific uncertainty attached to numerical models and has limited their usefulness for assessment and policy analysis purposes.

There is a scientific consensus that man-made emissions have increased the acidity of precipitation over eastern North America, but also that existing data and studies do not constitute an adequate basis for determining the details of past patterns in precipitation acidity. Problems with earlier determination of pH and other factors have called into question all previous attempts to define specific rates and patterns of increased precipitation acidity in eastern North America. Monitoring and research efforts are now underway that will allow improved interpretation of historical data and confident assessment of trends in the future.

Effects of Acid Deposition

For some lakes in sensitive regions, evidence has been gathered that indicates they have been acidified and experienced fisheries loss. The rate, character, and full extent of these changes remain major scientific unknowns. Few aquatic systems have been studied in sufficient detail to document the actual changes. Recent research has made it clear that the vegetation and soils surrounding a lake or stream play a major role in determining the rate and nature of the water body's response to acid deposition.

Many lakes in North America have complex watersheds where precipitation flows through forest canopies and soils, and is chemically modified before entering the lake. As rain passes over vegetation and through the soils, its acidity can be reduced or increased by many fold. Some watersheds may be vulnerable on the time scale of decades, while some others probably have the capacity to neutralize for centuries acid precipitation of the strength now falling. Surveys and detailed studies are underway or planned to determine and to predict the rates of change, and identify the most vulnerable aquatic resources.

Recent research and survey results have tended to reduce our concern about acid deposition damage to crops, while increasing general concern about possible effects on forests. Sulfur and nitrogen, the basic ingredients of acid rain, are applied to crops by farmers in fertilizers at many times the rate they are deposited by precipitation. The few relevant studies to date suggest the most commonly planted varieties of crops are not highly susceptible to acid deposition, although some cultivars have shown reduced yield. Laboratory and field studies are being conducted to assess more completely the effects of actual acid deposition on crops.

Forests in North America and Europe are showing environmental stress, the causes of which are a topic of scientific debate. Evidence analyzed during the past three years indicates that significant changes in growth and vitality of some species have occurred in the eastern United States forests. Based on regional assessment of both mortality and growth declines, it is apparent that a systematic and sustained growth decline of some species has been underway in the last 20-30 years. Extensive dieback and decline of red spruce has occurred in the high elevation forests of New England, resulting in up to 60% mortality in some stands during the past 20 years.

Growth reductions and increased mortality are also evident in the southern Appalachian mountains including North Carolina and Tennessee. The symptoms of decline of red spruce in New England and of Norway spruce in Germany appear similar in some respects and very different in others. The observed changes include initial loss of needles from the top and outside the canopy with gradual loss of vigor of the tree, slowed growth, and ultimately mortality. Growth of other species, principally fir, pitch and shortleaf pine has decreased significantly within the past 20 years in the northeast. It appears that forests in the U.S. may be responding to stresses which have been occurring for the past 2 to 3 decades.

To date, the evidence that acid deposition and associated man-made pollutants have contributed to observed forest declines is circumstantial and inferential rather than conclusive. The evidence is as follows: The declines appear to be most severe in regions with highest levels of acid deposition, ozone, and SO_2; they are manifested at about the same time as regional scale pollution was increasing; they do not show a consistent association with drought as a causative factor; and they do not appear to be the result of tree aging since both old and young trees have been affected at the same time. Conclusive demonstration of mechanisms of action of acid deposition _per se_ on forest growth have not yet been provided. Available evidence seems to support combined pollutant effects on foliage, although soil mediated processes can not be ruled out at this time. A variety of complex causes are possible and plans for accelerated work are underway to determine which factors -- such as acid deposition, gaseous pollutants, insects, disease, and drought -- contribute to the observed damages.

Germany has experienced documented forest damage that appears to be spreading. Initial hypotheses focused on acid deposition and aluminum toxicity in soils as the main culprits. Recently, other factors, such as gaseous air pollutants, have been hypothesized to be the causes. The many different hypotheses now proposed to explain the damages are being explored. International efforts are underway to work cooperatively in determining the causes, character, and extent of the observed forest changes in Europe and North America.

European and American evidence indicates that air pollution, including acid deposition, significantly accelerates the weathering of materials and cultural resources, and can reduce expected service life. The principal air pollutants causing materials damage are SO_2, NO_x, ozone, and particulate matter. The damage to materials from wet and dry deposition is cumulative, and both distant and local sources contribute. However, because pollutants are rarely encountered individually and are thought to act synergistically, they must be examined in combination and in different proportions corresponding to actual conditions. Possible damage includes corrosion of metals, erosion and discoloration of paints, and decay of building stone -- all of which also occur as a result of natural environmental conditions, even in unpolluted atmospheres.

Information about effects on materials from acid deposition needs to be better defined including: the extent of materials damage attributable to man-made pollutants, like acid deposition; the rate of degradation; a quantitative evaluation of the processes involved; and a reliable estimate of the materials at risk. Under the National Program, an inventory of materials at risk in the United States is being compiled, and other crucial analyses are underway.

As science advances our understanding of the acid rain issue, data are collected and analyzed, and many different hypotheses are proposed to explain the observed phenomena. Experiments must be designed to test the scientific validity of the various possible explanations. The existence at any one time of several possible explanations can confuse and dismay decisionmakers and the public. But scientific inquiry into complex environmental issues rarely, if ever, can provide simple clear cut answers. The search for understanding is often laborous, while the demands on policymakers are urgent and immediate. The public and decisionmakers understandably become impatient. Yet, only by careful research can a better information basis for decisions be developed.

Addressing the acid rain issue effectively requires both research and appropriate environmental policies. Objective scientific information is only one input, albeit an important one, to developing environmental policies. Policymakers, not researchers, must decide when there is adequate information for them to make a given decision. The scientists can define at any point in time what is known, with what level of certainty, and what isn't yet known.

Questions policymakers must also address require making a host of subjective judgments for which scientists have no special expertise. For example, scientists have the task of relating the response of ecosystems to the amount of acid deposition they receive; but it is the role of the policymaker to determine whether deposition should be limited, and by how much considering the societal costs and benefits of prescribed actions.

Although one major goal of the National Program is to quantify such costs and benefits, often costs and especially benefits cannot be quantified reliably, and subjective value judgments are needed to supplement scientific analyses. Science does not provide a basis for making such value judgments -- those judgments are the role of the policymaker. However, the confidence in selecting the most effective actions to yield the desired environmental results can be improved greatly by enhanced scientific understanding.

PROGRAM ACCOMPLISHMENTS

The National Program has resulted in many specific accomplishments during its second year of research in FY 1983. Some highlights of the advancements during 1983 and their significance to the research effort were as follows:

Natural Sources

- Measured sulfur compounds in the Gulf of Mexico and Northern Pacific Ocean.
  Significance: Quantifies the potentially important contribution of natural sulfur compounds in seawater.

- Modeled photochemistry induced by lightning to assess this source of natural NO_x emissions.
  Significance: Quantifies nitrate contribution from lightning as a significant portion of total natural background (approximately 25%).

- Developed and tested a fast response nitric oxide chemiluminescence detector.
  Significance: Facilitates measurements at low concentration and allows direct measurement of fluxes for the first time.

Man-made Sources

- Completed a preliminary draft of an improved 1980 Emissions Data Base for sulfur dioxide, nitrogen oxides, total volatile organic compounds, and particulate matter emissions for point sources and area sources in the 48 states.
  Significance: Improves data base for updated models and assessments.

- Developed a state-level version of the Advanced Utility Simulation Model.
  Significance: Facilitates regional forecasts of emissions and of control costs.

Atmospheric Processes

- Conducted the Cross Appalachian Tracer Experiment (CAPTEX) jointly with Canada, that tracked clouds of inert tracer from five releases at Dayton, Ohio, and two at Sudbury, Ontario, across northeast North America.
  Significance: Will verify modeling of long-range transport and dispersion.

- Conducted long-range air transport studies of dust and other materials using back-trajectory climatology to track air mass movement in different parts of the world.
  Significance: Help evaluate significance of long-distance transport of pollutants to remote regions.

- Established three dry deposition field research sites in conjunction with the Deposition Monitoring Task Group's National Trends Network.
  Significance: Provide prototypes for development of a national dry deposition measurement network.

- Modeled wet and dry deposition of sulfur for 1980 and 1981 using one of the available models, namely the Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) model, to derive state-wide annual deposition maps.
  Significance: Refines regional deposition maps for comparisons of impacts.

- Developed an airborne, two wavelength lidar (luminescent) system that can locate specially tagged air masses long distances from sources.
  Significance: Allows pollution plume tracking at long distances.

Deposition Monitoring

- Installed 17 new stations in the National Trends Network.
  Significance: Fill gaps in wet deposition monitoring data base.

- Tested new equipment to develop sequential precipitation samplers, to study fog removal of particles from the air, to determine the origin of acidity in remote areas, and to assess diurnal and seasonal variations in acidity.
  Significance: Improves the reliability and breadth of special studies.

- Conducted field evaluations of prototype dry deposition monitors.
  Significance: Necessary for creation of dry deposition monitoring network.

- Established an Acid Deposition System for data base management of all acid deposition monitoring sites in North America.
  Significance: Permits more timely and comprehensive data analyses.

Aquatic Effects

- Completed an inventory of existing water quality data on the lakes, streams, and groundwaters of the United States to assess the extent and degree of sensitivity to acid deposition.
  Significance: Provides a baseline for damage assessment.

- Established a network of long-term monitoring stations at lakes and streams across the country to correlate changes in water quality related to deposition.
  Significance: Improves ability to detect changes over time.

- Began a controlled lake acidification field experiment.
  Significance: Improves understanding of mechanisms of biological and chemical effects.

- Initiated laboratory and field tests to lime lakes sensitive to acid deposition.
  Significance: Allow better techniques for mitigation of acidification damage to be determined.

- Studied the quality of drinking waters and source waters in the Northeast for mobilization of heavy metals at different pH levels for a possible indirect health effects linkage with acid deposition.
  Significance: Preliminary results indicate many of the waters surveyed are corrosive but levels of metals did not exceed EPA maximum contamination levels.

Terrestrial Effects

- Initiated a major study of forest productivity in the eastern United States.
  Significance: Preliminary results suggest significant patterns of growth reduction for several species at numerous locations.

- Studied trace element accumulation in tree rings over long-term cylces.
  Significance: Provides insight into historic deposition patterns by correlation of iron accumulation with emissions.

- Conducted numerous studies of the effects of simulated acid rain on seedlings of yellow poplar, loblolly pine, red spruce, and other sensitive species.
  Significance: Indicate no effects at or above pH 3.6.

- Conducted numerous forest soils studies.
  Significance: Show large variation in the physical and biological ability of soils to buffer acid rain, to convert sulfate to less mobile sulfur compounds, or to leach metals from the soil because of sulfate deposition.

- Conducted numerous sophisticated crop field tests of simulated acid rain effects.
  Significance: Show little change in productivity on corn, soybeans or potatoes at pH as low as 3.4 (one variety showed a 10% change at pH 4.2).

Effects on Materials and Cultural Resources

- Completed a broad study of tombstones cut from the same or similar quarries over the last several decades.
  Significance: Shows significantly more damage in urban areas where local sources of pollutants are most concentrated.

- Established four field exposure test sites to define the deterioration rates of Indiana limestone, Vermont marble, and seven metals. Simultaneous measurement of meteorological conditions, wet acidic deposition, air quality measurements, and wetness is part of the exposure test program.

Significance: Provide a baseline for scientific analysis of corrosion and weathering of building materials.

- Initiated project to inventory the distribution of common building materials and cultural properties.
  Significance: Provides quantification of data base for assessing total materials damage.

- Began project to compile service life and cost data on major construction materials and components.
  Significance: Provides more realistic cost estimate for incremental effects of acid deposition.

Control Technologies (Funds for the development of SO_2 and NO_x control hardware are not included in the interagency budget of the National Program; they are appropriated under other programs of the agencies. The Control Technologies Task Group coordinates these efforts with the research and assessment activities of the National Program.)

- Improved capture of sulfur dioxide has been made possible by development of more active limestone sorbent for use with the Limestone Injection Multistage Burner (LIMB) process.
  Significance: Allows for potentially more cost-effective control of sulfur dioxide.

- Documented performance tests of the adipic-acid-enhanced limestone flue gas desulfurization (FGD) which allows greater than 90 percent SO_2 control from high-sulfur coal applications.
  Significance: Allow increased removal efficiency and improved reliability of limestone FGD.

- Developed an advanced heavy oil burner for industrial boilers that can reduce nitrogen oxides by 85 percent, and when applied commercially should be widely effective.
  Significance: Provides lower cost of controlling acid forming nitrogen oxides.

Assessments

- Prepared "The Critical Assessment Review Papers" on the state of the science of acid rain.
  Significance: Brings together in one document a summary of past studies and analyses about acid rain effects and damage.

- Adapted the Advanced Utility Simulation Model for use in the integrated assessment methodology.
  Significance: Integrates the use of models with overall assessment of impacts.

- Developed an integrated assessment methodology for future assessment of impacts from acid deposition.
  Significance: Provides a framework for assessing the combined influences of acid deposition on ecosystems.

International Activities

- o Met with the Canadian Research and Monitoring Coordinating Committee (RMCC) to review ongoing bilateral projects and to discuss future joint activities.
  Significance: Expands bilateral cooperation in acid rain research including adopting 12 new U.S.-Canadian projects.

- o Met with representatives from the research effort in the Federal Republic of Germany to arrange an exchange of U.S. and German scientists and to develop cooperative research.
  Significance: Increases exchange of information and begins planning of cooperative research.

- o Jointly sponsored international conference on forest damages with Canadians.
  Significance: Brought together experts on this important topic to share information and plan cooperative research.

- o Participated in several international organizations' concerned with acid deposition, such as the U.N. Economic Commission for Europe.
  Significance: Establishes greater cooperation and planning for international acid rain research efforts to address the issue and share information.

NATIONAL PROGRAM MANAGEMENT ACTIVITIES

The Task Force is conducting a National Program that coordinates the Federal efforts with the activities of the states, private sector groups, universities, research institutes, environmental groups, and other countries, especially Canada. Several specific actions have been taken to develop and encourage such cooperation and more extensive joint planning activities are anticipated. Such activities include:

National Plan Workshop

Besides a public review of the draft plan of the National Program, the Task Force's April 1981 workshop of non-Federal experts began a dialogue with states, and private sector and environmental groups. The workshop report describes the participants' ideas concerning how coordination and cooperation can best be accomplished. The Task Force is implementing many of these suggestions and is actively pursuing continued exchanges of information with non-Federal groups.

Annual Meeting

The Task Force holds an annual meeting, which provides a mechanism to bring together the full spectrum of research managers and scientists, to facilitate dialogue about the National Program and foster integration of its various elements, and thus enhance program unity.

The theme for the second annual meeting of the National Program (January 1984) was "Research to Assist Decisionmaking". The primary purpose was to enhance the dialogue between decisionmakers and the scientific community -- users and producers -- regarding what information is needed by decisionmakers, what information is available, and what research can provide. Attention focused on the outputs, timing and significance of planned research; priorities for research; the inherent limitations of the scientific research; and ways to improve the communication of results to decisionmakers. Many different perspectives for improving the dialogue were represented, including congressional staff, university researchers, industry, environmental groups, Federal agencies, and state governments.

Scientific Peer Reviews

An integral aspect of managing the National Program is providing a mechanism to rigorously examine research results, and review proposed and ongoing projects. Through the peer review process, external experts from academic institutions, the private sector, environmental organizations, states and other nations critically evaluate adequacy and comprehensiveness of the National Program as well as the quality of the scientific work. The reviews focus on the relevancy and interrelationship of the various research projects to the national effort, and the application of research results to assessment purposes.

The first full review of all aquatic and terrestrial effects research was held in February 1983. The natural sources, man-made sources, atmospheric processes, and deposition monitoring work underwent peer review in August 1983. The first complete cycle of the peer review process ended with the review of the materials effects and the assessments research, held in February 1984.

Detailed comments from the reviews are distributed to the appropriate agency managers and researchers. The Task Force and its member agencies use the information generated by the reviews to help guide the National Program with decisions on project funding and research direction. Summary reports of the peer reviews are produced and made available to all participants and interested parties.

Federal-State-Private Sector Coordination

In November 1982 the Task Force initiated and jointly sponsored, with the Electric Power Research Institute and others, the "Acid Deposition Research Coordination Workshop". This encouraged cooperation and coordinated planning between Federal research efforts under the National Program and the research activities of state and local governments, the private sector, and environmental organizations.

The meeting participants collectively developed statements concerning the scope of the research effort in the United States, future research needs, and plans for information distribution. The Task Force agreed to investigate increasing opportunities for state and private sector participation in the National Program. The state representatives agreed to organize by regions to identify needs, expertise and resources. Since the workshop, National Program representatives have participated in several meetings with the states to help identify specific research needs of their regions.

Preparation for a follow-up meeting to discuss progress on coordination of research is well underway. Additional topics will include an update of research projects established since the first meeting, and development of mechanisms for collaborating on all phases of research. The meeting will again be jointly sponsored by Federal and non-Federal groups.

A tangible example of joint planning and cooperation is in the establishment of the Coordination Working Group for Atmospheric Field Experiments. This group is designed to assure timely communication among the separate research programs for planning and analysis purposes, and to prepare recommendations for integrating and coordinating substantial field measurement programs. This will promote the effectiveness of field study plans for investigating the relationship between pollutant emission sources and acid deposition.

Currently the Working Group is involved in developing plans for major field experiments to better understand the relationship between sources and deposition at specific locations. The purpose is to gain empirical information that will help develop efficient control strategies with the ultimate goal of providing sufficient information to assess alternative acid deposition control strategies. A large scale field measurement program such as this is more successfully undertaken by using all available resources. Planning and feasibility studies include representatives from the National Program, the Canadian government, and the Electric Power Research Institute.

International Cooperation

The National Program includes a number of activities involving cooperation with the research efforts of other nations. Task Force members meet at least annualy with their Canadian counterparts, the Research and Monitoring Coordinating Committee (RMCC). A meeting to review ongoing bilateral projects and discuss proposals for increasing joint U.S./Canada acid rain research was held in July 1983. Twelve ongoing projects were identified, and proposals for 21 more were discussed, ranging from atmospheric modeling and monitoring, to forestry effects research and data base intercomparisons. The representatives have identified appropriate U.S. and Canadian contacts for each proposed project, and will proceed with projects contingent on final funding decisions. The third annual U.S./Canadian research meeting will be held here in a few weeks (May 1984).

Task Force members also met with representatives of the research effort in the Federal Republic of Germany during FY 1983. There is strong mutual interest in developing cooperative research on atmospheric processes and forestry. Exchanges of U.S. and German scientists have been arranged to visit each country's monitoring and effects research sites and to develop plans for further cooperation.

The U.S. National Program is also working with other nations' research efforts under the U.N. Economic Commission for Europe Convention on Long-range Transboundary Air Pollution. Plans for an international effort of standardizing methods and proposing multilateral activities are being developed for approval by the Convention's Executive Body in September 1984.

Inventory of Acid Rain Research Projects

The National Program has established a computer inventory of project descriptors for all the Federally-funded research. The inventory includes information on all ongoing projects with the performer(s), duration, funding, study area, research goals, methodologies, and expected outputs. The computer inventory is being maintained and updated for use by the Task Force, and all interested parties. Work will begin in FY 1984 on the inventory of all state-sponsored research and monitoring acitvities. The private sector has conducted a similar inventory of its activities; together with the Task Force's effort, this should provide a complete catalog of all acid deposition research and monitoring activities in the United States.

Information Dissemination

The National Program served as the catalyst and hosted a meeting on acid rain information sources in October, 1983. This meeting brought together sponsors, producers and users of bibliographies and research project inventories on acid rain. Presentations were made on the status and outlook for these services, with the focus on the scope and purpose, dissemination and availability, and identification of user needs. The interaction between the participants was encouraging, and greater cooperation is anticipated for the future.

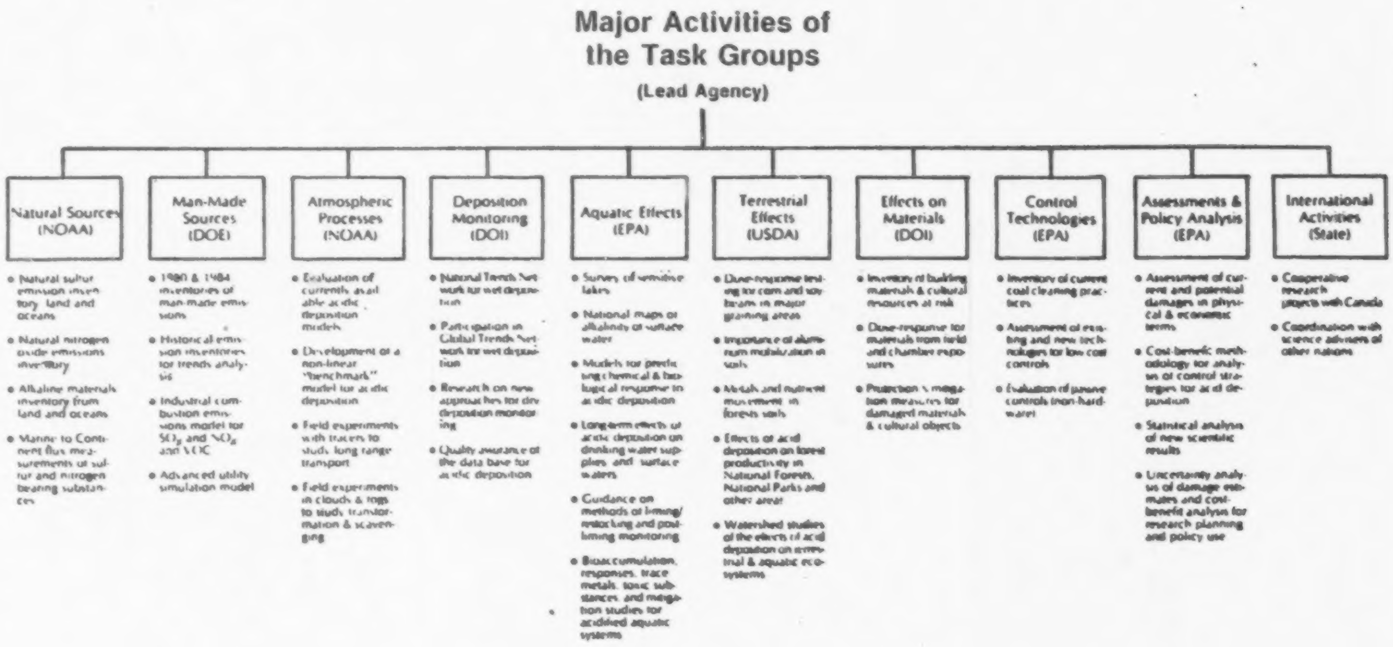
SUMMARY

The research and monitoring activities of the National Program are designed to provide successively better tools and a continually improved information base for developing and implementing sound policies to achieve the maximum environmental benefit at the minimum societal costs. As Congress recognized in creating this long-term, broad-based program, the issue is exceedingly complex and has required advancing the frontiers of science in fundamental areas of ecology and atmospheric sciences. Pioneering is not easy or quick, no matter how urgent the need to understand a new area.

The National Acid Precipitation Assessment Program (NAPAP) has already produced many important outputs, described in our annual reports. Given the acceleration of research under the National Program, by the private sector, states, and other nations, major strides forward in our understanding can be expected.

Figure 1

National Acid Precipitation Assessment Program



Major Activities of the Task Groups

(Lead Agency)

Natural Sources (NOAA)

- Natural sulfur emission inventory, land and oceans
- Natural nitrogen oxide emissions inventory
- Alkaline materials inventory from land and oceans
- Marine to Continent flux measurements of sulfur and nitrogen bearing substances

Man-Made Sources (DOE)

- 1980 & 1984 inventories of man-made emissions
- Historical emission inventories for trends analysis
- Industrial combustion emissions model for SO_x and NO_x and VOC
- Advanced utility simulation model

Atmospheric Processes (NOAA)

- Evaluation of currently available acidic deposition models
- Development of a non-linear "benchmark" model for acidic deposition
- Field experiments with tracers to study long range transport
- Field experiments in clouds & fogs to study transformation & scavenging

Deposition Monitoring (DOI)

- National Trends Network for wet deposition
- Participation in Global Trends Network for wet deposition
- Research on new approaches for dry deposition monitoring
- Quality assurance of the data base for acidic deposition

Aquatic Effects (EPA)

- Survey of sensitive lakes
- National maps of alkalinity of surface water
- Models for predicting chemical & biological response to acidic deposition
- Long-term effects of acidic deposition on drinking water supplies and surface waters
- Guidance on methods of liming/restocking and post-liming monitoring
- Bioaccumulation, responses, trace metals, toxic substances, and migration studies for acidified aquatic systems

Terrestrial Effects (USDA)

- Dose-response testing for corn and soybeans in major growing areas
- Importance of aluminum mobilization in soils
- Metals and nutrient movement in forests soils
- Effects of acid deposition on forest productivity in National Forests, National Parks and other areas
- Watershed studies of the effects of acid deposition on terrestrial & aquatic ecosystems

Effects on Materials (DOI)

- Inventory of building materials & cultural resources at risk
- Dose-response for materials from field and chamber exposures
- Protection & mitigation measures for damaged materials & cultural objects

Control Technologies (EPA)

- Inventory of current coal cleaning practices
- Assessment of existing and new technologies for low cost controls
- Evaluation of passive controls (non-hardware)

Assessments & Policy Analysis (EPA)

- Assessment of current and potential damages in physical & economic terms
- Cost-benefit methodology for analysis of control strategies for acid deposition
- Statistical analysis of new scientific results
- Uncertainty analysis of damage estimates and cost-benefit analysis for research planning and policy use

International Activities (State)

- Cooperative research projects with Canada
- Coordination with science advisers of other nations

Funding history of National Acid Precipitation Assessment Program

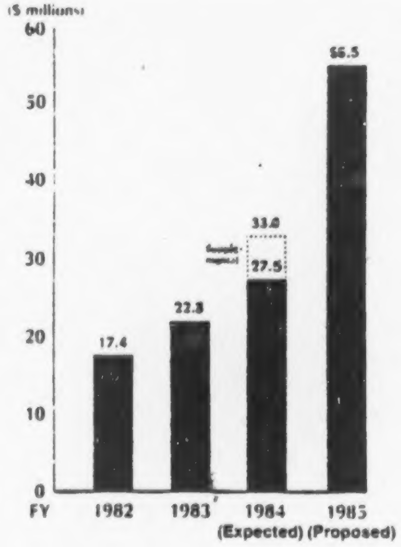


Figure 2

Table 1

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

FY 1984 BUDGET
($ in thousands)

	EPA	USDA		NOAA	DOE	DOI				TOTAL
		SE	FS			PS	GS	FW	BLM	
A. Natural Sources				855						$ 855
B. Man-made Sources	1090				260					1350
C. Atmospheric Processes	5250			1020	270					6540
D. Deposition Monitoring	1789	274	146	1130	942	122	1870		80	6353
E. Aquatic Effects	2285		210		550	148	445	125		3763
F. Terrestrial Effects	1468	946	1258		50	229	486			4437
G. Effects on Materials	605					740	150			1495
H. Control Technologies	(4100) *				(7000) *					(11,100) *
I. Assessments	1500				1175					2675
Subtotals:		1220	1614			1239	2951	125	80	
TOTALS:	$ 13,987	2834		3005	3247	4395				$ 27,468

* Funds for the development of SO_2 and NO_x control hardware are not included in the interagency budget of the National Program. Funding for these particular items are appropriated under other programs of the agencies. The Control Technologies Task Group coordinates these efforts with the research and assessment activities of the National Program.

Table 2

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM

President's Budget Request
FY 1985
($ in thousands)

		USDA					DOI					
	EPA	CSRS	ARS	FS	NOAA	DOE	PS	GS	FW	BLM	TOTAL	%
A. Natural Sources					855						855	1.5
B. Man-made Sources	1200					750					1950	3.5
C. Atmospheric Processes	10,576				1005	5260					16,841	30.3
D. Deposition Monitoring	4357	248		146	500	977	322	1870		80	8500	15.3
E. Aquatic Effects	8022			210		150	148	445	1525		10,500	18.9
F. Terrestrial Effects	5610	1045	384	1758		120	329	486			9732	17.5
G. Effects on Materials	975						970	150			2095	3.8
H. Control Technologies	600										600	1.1
I. Assessments and Policy Analysis	3025					1400					4425	8.0
Subtotals:		1293	384	2114			1769	2951	1525	80		
TOTALS:	34,365	3791			2360	8657	6325				55,498	
(%)	(61.9)	(6.3)			(4.3)	(15.6)	(11.4)					

The **Chairman**. Thank you very much.

I do apologize. Evidently we have run into the noon hour, and we run into many conflicts and other members of the committee are going to have to read the record and read your statements rather than listen to your statement. I apologize for that, but that is a fact.

Dr. Kasper, your entire statement will be placed in the record, I would invite you to highlight what portions of it you would like to highlight, or make any other remarks outside the statement itself.

STATEMENT OF DR. RAPHAEL G. KASPER, EXECUTIVE DIRECTOR, NATIONAL RESEARCH COUNCIL, COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES, NATIONAL ACADEMY OF SCIENCES/NATIONAL ACADEMY OF ENGINEERING

Dr. **Kasper**. Thank you.

My purpose in the testimony is to describe briefly the findings and conclusions of the National Research Council report issued last summer entitled, "Acid Deposition: Atmospheric Processes in Eastern North America," which was described earlier this morning as the much-misconstrued National Academy of Sciences report. And that's probably an apt description.

The report was prepared by a committee of experts chaired by Jack Calvert, an atmospheric chemist at the National Center for Atmospheric Research in Boulder.

Dr. Calvert asked me to fill in for him today, and he regrets that an unavoidable commitment prevents him from being here.

The report reviews a great deal of available data, laboratory experiments and theoretical calculations relating to processes of acid rain in eastern North America.

The focus was on this region, not because it's the only region in which acid deposition is a problem, but because most of the available data are from this region.

Now, let me note that the report did not explicitly address questions of control technology and techniques. So that any comments you may have heard about the National Academy of Sciences' position, either pro or con, are matters of control technology and techniques involved reading more into the report than in fact is in the report. Let me just briefly say what is in the report.

The report concludes that contrary to an earlier hypothesis, there is no evidence of a strong nonlinearity in the relationship between aggregate emissions of sulfur oxides and aggregate deposition of sulfuric acid in precipitation in eastern North America.

This means that a reduction in total emissions over a large area of the eastern part of the continent is likely to lead to an approximately proportionate reduction in spatially integrated, annual average deposition in this area.

By "proportionate" we mean that a 20-percent reduction in emissions would lead to a 20-percent reduction in deposition; a 40-percent reduction in emissions to a 40-percent reduction in deposition and so forth.

But, given currently available models, we cannot, with any reasonable accuracy, say anything about the detailed relationship between emissions from specific sources——

The **Chairman**. Can I interrupt and go back to the the first point that you made.

You say there is no evidence of a strong nonlinearity, and then you make a statement that leads—this means, is there strong evidence of linearity?

Dr. **Kasper**. We know that the processes of atmospheric deposition are nonlinear; that there are nonlinearities in the individual processes, but it's a very complicated set of transformations in chemical reactions. And when averaged, as this group did, over a very large area and over a long time, like a year, the strong nonlinearities seem to disappear, and you get a proportionate relationship.

The **Chairman**. I'm trying to understand as a layman what you're saying in technical terms.

Are you saying what goes up comes down, and if it doesn't go up it can't come down?

Dr. **Kasper**. One way of characterizing that conclusion is that if you look at a big enough area in a long enough time, what goes up comes down.

The **Chairman**. But you can't say whether that's true in any particular area, or any particular pollutant?

Dr. **Kasper**. That is correct, with one small exception that I'll get to in a moment.

The **Chairman**. All right. Continue, please.

Senator **Ford**. Well, let me ask one other question.

Can you talk without using a double negative? [Laughter.]

I'm serious. You say no and non. You know it's just—I'm looking at page 2 and——

Dr. **Kasper**. That's right. And I follow it up by saying that what it means is that if emissions over a large area were reduced by a certain amount there would be an approximately proportionate reduction in spatially integrated, annual average deposition.

Senator **Ford**. What is approximate—in the eye of the beholder?

Dr. **Kasper**. Well, it's very hard to—yes.

Senator **Ford**. Thank you very much.

Thank you, Mr. Chairman.

Dr. **Kasper**. Now, the one place where the committee did make an explicit conclusion about what would happen at particular sites was in its conclusion that if emissions of sulfur dioxide were changed throughout eastern North America in such a way that spatial patterns remained unchanged, we would expect a proportionate change in the magnitude of deposition of sulfuric acid throughout the region, and the spatial distribution of acid rain would not be changed in such a circumstance.

Finally, the committee asked for the development of better models so that the source-receptor relationships could be characterized in a better and possibly more useful way.

Let me just finish by saying a little bit about some other work the Academy's doing, because it's been alluded to earlier this morning. And although the request was to look at the Calvert report, I think you would be interested in hearing what has been going on since the Calvert report was issued at the Academy.

Last July, at the request of Mr. Ruckelshaus, the National Academy of Sciences and National Academy of Engineering convened a roundtable discussion of 15 scientific experts in the field to help determine points of scientific agreement and disagreement in a number of existing analyses of atmospheric transport and transformation as they relate to acid rain.

And that meeting led to a remarkably high degree of consensus about some general things, like the general conclusion of the Calvert report, but again agreement that the state of models right now won't permit a much more detailed description of source-receptor relations.

Last month, again at the request of Mr. Ruckelshaus, we convened a panel of experts to explore processes occurring in watersheds that lead to acidification of lakes, and it is that report that Mr. Ruckelshaus referred to earlier.

The report, in fact, is merely a summary of a 4-hour discussion among a group of nine scientists. And one of the reasons for Mr. Ruckelshaus' characterization that the scientists were divided is that the group of nine scientists was chosen for their diversity of views, and we only let them talk for 4 hours before we cut them off.

We have another committee that Chris Bernabo mentioned, chaired by Prof. James Gibson of Colorado State University that is examining long-term trends in acid deposition and problems of monitoring acid deposition.

That is a longer effort, and we expect to have a report sometime next winter.

And finally, the National Academy of Sciences is continuing its work with our sister academies in Canada and Mexico in our joint sponsorship of a triacademy committee on acid precipitation, which has been reviewing research and monitoring programs all over North American, with a view towards fostering coordination and cooperation among the scientific communities of this continent.

Thank you.

[The prepared statement of Dr. Kasper follows:]

TESTIMONY OF RAPHAEL G. KASPER

National Research Council
of the
National Academy of Sciences/National Academy of Engineering

UNITED STATES SENATE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
April 30, 1984

I am Raphael Kasper. As Executive Director of the National Research Council's Commission on Physical Sciences, Mathematics, and Resources, one of my responsibilities has been to supervise the preparation of reports on the topic of acid rain. The most recent activities of the Academy complex in this area have been--and continue to be--conducted under the auspices of our Environmental Studies Board, a subdivision of the Commission.

My purpose today is to describe to you briefly the findings and conclusions of the NRC report issued last summer titled Acid Deposition: Atmospheric Processes in Eastern North America. The report was prepared by a distinguished committee of experts chaired by Jack G. Calvert, an atmospheric chemist currently at the National Center for Atmospheric Research in Boulder, Colorado. Dr. Calvert asked that I fill in for him today; he regrets that an unavoidable commitment prevents him from being here.

The report is a carefully documented review of the currently available data, laboratory experiments, and theoretical calculations that help us to understand the phenomenon of acid rain in eastern

North America. The focus of attention was on this region because most of the available data are from this region. The report did not explicitly address questions of control technology and techniques. Let me briefly list the most important results.

1. Contrary to an earlier hypothesis, there is no evidence of a strong nonlinearity in the relationship between aggregate emissions of sulfur oxides and aggregate deposition of sulfuric acid in precipitation in eastern North America. This means that a reduction in the total emissions over a large area in the eastern part of the continent is likely to lead to an approximately proportionate reduction in the spatially-integrated, annual average deposition in this area. By "proportionate" we mean that a 20% reduction in emissions would lead to a 20% reduction in deposition, a 40% reduction in emissions to a 40% reduction in deposition, and so forth.

2. Given currently available computer models, we cannot confidently determine with reasonable accuracy the detailed relationship between emissions from a specific source or highly localized source region and acid deposition in a specific receptor area hundreds of miles away. Thus, while we know the general relationship between average aggregate emissions and deposition, we cannot predict the extent to which acid deposition would be reduced at a given site as a result of restricted emissions from a particular source.

3. If emissions of sulfur dioxide were changed throughout eastern North America in such a way that the spatial pattern of

emissions remained unchanged, we should expect a proportionate change in the magnitude of the deposition of sulfuric acid throughout the region. The spatial distribution of acid rain would not be changed in such a circumstance. A substantial change in the spatial pattern of emissions would in all likelihood lead to a change in the spatial pattern of acid deposition, but as I have indicated, we cannot now predict with reliability how the pattern of deposition would change.

4. The development of improved models that can be used to calculate source-receptor relationships with high confidence and accuracy will require support from additional studies of the physical and chemical processes that determine the motions and transformations in air parcels under meteorological conditions typical of acid rain episodes in eastern North America.

The members of our committee arrived at these conclusions after reviewing the pertinent literature and available data and after conferring with colleagues in the United States, Canada, and Europe. We hope that readers of the report will consider carefully both the supporting arguments and the uncertainties associated with the findings. I believe it is accurate to say that the report has been widely accepted in the international scientific community. The report recognizes that there is much more to learn about acid deposition and recommends avenues for research to further our understanding of this complex atmospheric phenomenon.

Before concluding my testimony today, I would like to mention briefly the work that the Academy complex has done in this area since the Calvert report was issued.

Last July, at the request of EPA Administrator Ruckelshaus, the National Academy of Sciences and National Academy of Engineering convened a roundtable discussion of 15 scientific experts in the field to help determine points of scientific agreement and disagreement in a number of existing analyses including the Calvert report and the report of a panel gathered by the Office of Science and Technology Policy. Last month, again at the request of Mr. Ruckelshaus, we convened a panel of experts to explore the processes occurring in watersheds that lead to acidification of lakes.

We have another committee, chaired by Professor James Gibson of Colorado State University, examining long-term trends in acid deposition and problems of monitoring. This committee is scheduled to issue its report next winter. Its work is supported by funds from EPA, the U.S. Geological Survey, and a consortium of philanthropic foundations. Finally, we continue to work with our sister academies in Canada and Mexico by jointly sponsoring a Tri-Academy Committee on Acid Precipitation, which reviews research and monitoring programs in North America with a view toward fostering coordination and cooperation among the scientific communities of the continent.

Senator FORD [presiding]. Thank you.
Dr. Manowitz.

STATEMENT OF DR. BERNARD MANOWITZ, CHAIRMAN, DEPARTMENT OF APPLIED SCIENCE, BROOKHAVEN NATIONAL LABORATORY

Dr. MANOWITZ. Thank you, Senator Ford.

In view of the time, I'll try to make my comments as short as I can. I will abbreviate some of the written testimony, which I assume will be placed into the record.

Senator FORD. That's without objection, there's no one here to object.

Dr. MANOWITZ. I'm the Chairman of the National Laboratory Consortium, a group of four national laboratories, Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory, that have a congressionally mandated role in the National Acid Precipitation Assessment Program.

That role, as we and the cochairs of the Interagency Task Force, have interpreted it, is both to assist the Interagency Task Force in the organization and coordination of the national program, and to conduct research on those portions of the program where the talents and facilities of the national laboratories are appropriate.

Research portions of the program are awarded to the national laboratories by individual agencies only after the proposal and review process appropriate to each agency.

Presumably Congress mandated this role to the national laboratories in order to provide a coherent core of experienced research and management capabilities, with facilities strategically located throughout the United States that could assist the many agencies of the Interagency Task Force in framing and implementing a consolidated, goal-oriented national program.

I am happy to report to you some of the key accomplishments of the National Laboratory Consortium as a subset of the accomplishments of the Interagency Task Force, and also some of the key benchmarks in a sequential strategy which the National Lab Consortium believes is necessary to advance an understanding of the causes and effects of acid deposition sufficiently so that decisions on control strategies can be provided with a strong scientific foundation.

The four laboratories of the consortium have been performing a variety of roles in acid deposition research, both in concert and individually on specific research efforts. That research in general predates the Acid Precipitation Act of 1980, and was responsible for the formation of the consortium as an aid to the National Acid Precipitation Program.

As a group, the laboratories mobilized experts in all of the key research areas and developed a strawman operational plan about 2 years ago.

The cornerstone of this plan was the role of the assessment process in focusing research to provide the answers needed by policymakers within the fine limits of uncertainty.

This nexus has now been adopted by the task force, and formal assessments are planned for fiscal 1985, 1987, and 1989, following the general outline developed by the National Laboratory Consortium.

The written testimony provides a list of accomplishments by the National Lab Consortium in atmospheric process research, deposition research, economic systems research, forest ecosystems research, aquatic ecosystems research, material sciences research, control technology research, and integrated assessments.

These accomplishments, along with many more by other participants of the Interagency Task Force, provide a running-start toward an understanding of the fundamental causes and effects of acid deposition.

The National Laboratory Consortium has selected three critical research areas for which more information is required to produce critical assessments pertaining to acid deposition.

The laboratories of the National Laboratory Consortium are able to mount comprehensive, coordinated-filled research efforts that will provide a thrust of new information to clarify important issues.

We hope these research efforts will shorten the time required to make scientifically defensible assessments. And, of course, it's intended that these programs will be closely coordinated with the national program.

These three key new programs are: First, one which we describe as nonlinearity of acid precipitation processes, which could also be described as linearity of acid precipitation processes.

The key question is, on what spatial scale is the deposition of acidic or acidifying pollutants proportional to the emissions of sulfur and nitrogen oxides?

The second important question is, has to do with air/surface dry exchange. And there the question is, what are the area average rates of deposition of atmospheric sulfur and nitrogen compounds for realistically diverse landscapes?

The final major program that we're suggesting has to do with watershed research. The key questions to be addressed by this research are: What are the contributions of the various biological and geochemical processes and hydrologic pathways to the delivery and processing of acidity, alkalinity, and aluminum to the aquatic system; and, second, what are the spatial and temporal variations of these processes and pathways through the terrestrial system and receiving waters?

The objectives of this research are to provide a quantitative understanding of the interactions among pollutants associated with acid deposition, and those biological and geochemical processes in aquatic and special ecosystems which control the rate and extent of surface-water acidification?

That concludes the formal remarks, Senator Ford. I'll be happy to answer any questions.

[The prepared statement of Dr. Manowitz follows:]

Testimony Before Senate Committee on
Energy and Natural Resources
April 30, 1984

INTRODUCTION

My name is Bernard Manowitz. I am the Chairman of the Department of Applied Science at Brookhaven National Laboratory. I am also the Chairman of the National Laboratory Consortium, a group of four National Laboratories, Argonne National Laboratory, Brookhaven National Laboratory, Oak Ridge National Laboratory, and Pacific Northwest National Laboratory, that have a Congressionally-mandated role in the National Acid Precipitation Assessment Program. That role, as we and the Co-Chairs of the Interagency Task Force have interpreted it, is both to assist the Interagency Task Force in the organization and coordination of the national program, and to conduct research on those portions of the program where the talents and facilities of the National Laboratories are appropriate. Research portions of the program are awarded to the National Laboratories by individual agencies only after the proposal and review process appropriate to each agency.

Presumably Congress mandated this role to the National Laboratories in order to provide a coherent core of experienced research and management capabilities, with facilities strategically located throughout the United States that could assist the many agencies of the Interagency Task Force in framing and implementing a consolidated, goal-oriented national program.

I am happy to report to you some of the key accomplishments of the National Labortory Consortium (NLC) as a subset of the accomplishments of the Interagency Task Force and some of the key benchmarks in a sequential strategy which the NLC believes are necessary to advance an understanding of the causes and effects of acid deposition sufficiently so that decisions on control strategies can be provided with a strong scientific foundation.

RECENT ACCOMPLISHMENTS OF THE NLC

The four laboratories of the Consortium have been performing a variety of roles in acid deposition research, both in concert and individually, on specific research projects. That research in general predates the Acid Precipitation Act of 1980, of course, and was responsible for the formalization of the Consortium as an aid to NAPAP. A summary of those accomplishments follows.

As a group, the Laboratories mobilized experts in all of the key research areas and developed a strawman operational plan about two years ago. The cornerstone of this plan was the role of the assessment process in focusing research to provide the answers needed by policymakers, with defined limits of uncertainty. This nexus has now been adopted by the Task Force, and formal assessments are planned for 1985, 1987, and 1989, following the general outline developed by the NLC.

In order to carry out the Task Force mandates, a support staff has been organized for NAPAP Task Group I (Assessments and Policy Analysis). The NLC is directly involved in this activity and has provided several individuals on detail to Washington as well as direct support activities at home laboratories.

1. Atmospheric Process Research

- Established the MAP3S (Multistate Power Production Pollution Study) Precipitation Chemistry Network in 1976. This research-quality network in the Northeastern United States collects precipitation samples on an event basis and conducts analyses for all chemical species of importance to the acid deposition problem. Data from this network has been used in numerous studies of deposition patterns.

- Completed field sampling for the OSCAR (oxidation and scavenging characteristics of April Rain) experiment. This experiment examined dynamic and chemical features of frontal storm systems over the northeast, provided increased understanding of wet removal mechanisms and provide data on pollutant source regions contributing to regional precipitation acidity.

- Established two precipitation collection networks (a) on a small scale (100 x 100 km region) with 50 stations, and (b) on a large scale with 37 stations from Illinois to New England. This was the ground sampling component of OSCAR.

- Evaluated the PLUVIUS models of in-cloud chemical processes using data from the small scale OSCAR precipitation sampling network.

- Documented spatial and temporal precipitation chemistry variability using the large-scale OSCAR sampling network.

- Established the OSCAR database to be used in source-receptor studies of acid deposition.

- Initiated a meso-scale acid deposition study and completed nine of the component studies. This will evaluate effects of urban emissions on precipitation chemistry. Preliminary results indicate urban areas contribute to precipitation acidity.

- Completed field components of CAPTEX (Cross Appalachian Tracer Experiment). This study documented long-range transport of a tracer plume at distances up to 1000 km.

- Demonstrated the utility and reliability of atmospheric tracer methods. As part of CAPTEX, ground and aircraft sampling studies followed 6 tracer releases from Dayton, OH, and Sudbury, Ontario.

- Developed ASTRAP (Advanced Statistical Regional Air Pollution) Model. This assessment model allows simulation of long-range transport of air pollutants and their deposition by wet and dry processes.

- o Described transboundary and interstate transport of air pollutants using ASTRAP. Analysis of proposed emission control strategies included modeling of wet and dry deposition under various atmospheric conditions, and studies of meteorological processes in the planetary boundary layer.
- o Developed PLUVIUS. This model studies chemical transformation and scavenging of pollutants in clouds and precipitation. It was used in the OSCAR experiment and many other experiments to illucidate in-cloud scavenging processes.
- o Adapted PLUVIUS for use as the scavenging module for comprehensive regional models of atmospheric physics and chemistry.
- o Prepared Dry Deposition Maps. These provide estimates of dry deposition velocities as a function of land use, season, and meteorological conditions and have been combined to develop regional estimates of dry deposition potential.
- o Conducted plume studies at a major coal-fired power plant. These studies indicate that less than 2% of the Hg in coal is captured by modern precipitators, greater than 90% is released as a vapor; the predominance of the vapor form is conducive to long-range transport of pollutants and their ultimate removal primarily by precipitation scavenging.

2. Atmospheric Chemistry:

- o Development of analytical methods. These included a filter pack, and methods for quantitative analysis of sulfate, sulfur dioxide, oxides of nitrogen including nitric acid, acidity of aerosols and NH_3.
- o Elucidated acid forming mechanisms. Clear air oxidation of sulfur dioxide to sulfate was described and cloud water oxidation mechanisms (SO_2 to $SO_4^{=}$ via H_2O_2) were identified.
- o Coupled the importance of mass transport and aqueous phase oxidation.
- o Identified the mechanisms of aqueous phase solubility and reactivity of nitrogen dioxide.
- o Identified, developed and exploited the use of inert tracers (perfluorocarbons) to study the mesoscale transport to pollutants.
- o Identified the potential importance of PAN (peroxyacetylnitrate) as a contribution to acid rain by determining its solubility and reactivity.
- o Developed an oxygen isotopic technique capable of examining the mechanisms of formation for ambient sulfate.

3. Atmospheric Deposition

- Investigated the relative importance of wet vs. dry deposition of acidic substance to the yield of soybean. This project examined the importance of acid rain in influencing the response of soybean and other crop species to ozone and sulfur dioxide. Evidence to date supports the hypothesis that the effects of simulated acid rain and ozone are additive in nature.

- Established three dry deposition monitoring stations, and began measurement/parameterization of dry deposition velocities for S- and N-compounds at the three sites.

- Measured dry vs. wet deposition at Walker Branch Watershed. Dry deposition equals or exceeds wet deposition in the annual flux of SO_4^{2-}, NO_3^-, H^+, Ca^{++}, and K^+ to a mixed deciduous forest as measured during an intensive two-year field study.

- Determined the importance of vapor phase HNO_3. Dry deposited vapor phase HNO_3 is a particularly important component of deposition, delivering 20% of the total input of H^+ and 50% of the NO_3^-, as a highly reactive gas.

- Determined the influence of elevation on atmospheric deposition. Atmospheric deposition increases several fold along a transect from lowlands to mountain tops in the eastern U.S. because of increased wet, dry, and cloud water deposition at high elevations.

- Developed a method to measure dry deposition rates to leaves. A method has been developed to extract surface deposited material directly from forest foliage for measurement of dry deposition rates to leaves and for comparison with surrogate surface measurements; results for SO_2^4, NO_3^-, K^+, and Ca^{++} indicate a quantifiable relationship between results of both methods.

- Determined the significance of large particles to total dry deposition. Large particles contribute significantly to the total dry deposition of several ions (e.g., SO_4, metals) and must be measured with surrogate surface methods because they are excluded by micrometeorological techniques.

- Determined the effect of deciduous forest canopies on atmospheric deposition. Reactions in deciduous forest canopies decrease the H^+ ion flux from the atmosphere to forest soils by as much as 50% due to ion exchange and weak base buffering; episodes of elevated ozone concentrations may temporarily disrupt these reactions.

- Evaluated impacts of regional emissions and synoptic weather patterns on precipitation chemistry. Precipitation chemistry at one site in the Southeast is not significantly influenced by local coal combustion but is influenced by regional emissions and synoptic weather patterns.

- Developed a model to predict wet deposition of SO_4^{2-} and several metals. Wet deposition of SO_4^{2-} and several metals can be predicted from rainfall amount using a power law relationship with an exponent of approximately 0.6; the exponent for the relationship between wet deposition of H^+ and rainfall is significantly higher (0.8) than the average value used in many models (0.6).

- Documented empirical source/receptor relationships between SO_2 emissions and deposition of SO_4^{2-}, NO_3^-, and H^+ in annual rainfall. Strong, approximately linear influences of local (0-570 km) sources, principally in the southwest quadrant, were found. Historical reconstructions of regional emissions/deposition patterns have been implemented based on definition of relevant source areas and historical SO_2 emissions.

4. Agronomic Systems

- Developed a rain exclusion shelter system (BNL-RES) to evaluate precipitation acidity effects on field-grown crops.

- Demonstrated that soybean crop yields may be reduced by ambient rain acidity (pH 4.1) with no foliar injury.

- Demonstrated that soybeans have differing varietal sensitivity to rain acidity.

5. Forest Ecosystems

- Evaluated acid deposition effects on forest nutrient dynamics, tree growth and biomass accumulation for a multi-species northeastern forest. In cooperation with university scientists, a forest-floor nutrient model (FORTNIT) was combined with a forest growth model. Results indicate long-term increase in nitrogen storage in forest litter and perturbations of forest and growth due to acid deposition.

- Determined the effect of atmospheric deposition on Pb, Cd, and Zn cycles. Atmospheric deposition dominates the cycle of Pb and has a significant influence on the cycles of Cd and Zn in a deciduous forest; deposition supplies from 40 to more than 90% of the annual flux of these metals to the forest floor.

- Evaluated interactions between dry deposition and acid precipitation on vegetation. These interactions result in concentrations of dissolved metals on leaf surfaces much higher than those in rain alone leading to direct uptake by foliage; this mechanism may be particularly important for Pb accumulation in woody biomass.

- Demonstrated that spermatophyte plant reproduction is inhibited by acidity of ambient rain (pH 4.1). Spermatophytes are major contributors to the understory of forest ecosystems.

- Characterized effects of natural vs. atmospheric sources of acid on soil leaching and acidification rates in various forest ecosystems. These studies estimate atmospheric H^+ inputs and H^+ production by natural carbonic and organic acid production in a variety of forest sites in the southeastern, northeastern, and northwestern United States.

- Determined combined effects of intensive harvesting, acid deposition, and natural leaching on nutrient budgets of a variety of forest ecosystems. This project encompasses all the assessments listed above, plus an assessment of harvesting effects on cation export as well.

- Determined soil properties related to sulfate retention capacity with the goal of mapping regional soil sensitivity to sulfate leaching. This research showed definite relationships between soil adsorption and soil properties related to the soil classification system, which aids in mapping sensitive soils.

- Determined the effects of acid deposition on the rates of nutrient cycling in forests and nutrient use efficiency. This is an ecosystem-level approach to assessing acid deposition effects which has been applied successfully to fire, fertilization, and harvesting, but not previously to acid deposition research.

- Designed and coordinated the multiagency collaborative project FORAST. This project is examining temporal and spatial patterns of forest tree growth during the past 50 years to determine regional correlations with patterns of acid deposition, gaseous pollution, and natural environmental stresses.

- Conducted milestone research to document historical patterns of trace element accumulation in tree rings. This research indicates increased uptake of aluminum and iron in the past 20-30 years. Highest concentrations of several trace elements have been found in the foliage, cambium, and phloem; tissue levels are high enough to suspect the possibility of direct toxic effects.

- Developed physiological indicators of crop and tree responses to stress from acid rain, ozone, and SO_2. These indicators may prove useful in characterizing primary responses of vegetation to pollution stress in the field.

6. Aquatic Ecosystems

- Quantitatively described snow-melt acid pulse effects on the chemistry of ice-covered Adirondack Mountain lakes. This may be a major factor in biological injury in northern lakes.

- Demonstrated surface water acidification in NH and NC by comparing historic water quality measurements and current water quality data obtained by a field sampling program.

- o Assembled ACID (Acidification Chemistry Information Database). This is a large database containing 200 million bytes of current and historical information from 50,000 water quality sampling stations throughout the U.S. It is available to various users associated with the NAPAP for assessment of historical patterns in surface water acidification and for developing predictive models of acidification.

- o Evaluated temporal and spatial trends in metal deposition at four southeastern watersheds. The results suggest that the relative contribution of dry deposition is both site and metal specific (ranging from 6% to 60% of total) and that the total deposition of Pb has decreased significantly from 1975 to 1982, parallel with the decrease in use of leaded gasoline.

7. Materials Sciences

- o Applied laser holographic moire interferometry to assess surface properties of rough-surfaced limestone exposed to acid deposition in the field.

- o Applied Twyman-Green interferometry to smooth limestone surfaces as a short-term measure of roughening.

- o Developed stone surface chemistry methodology and explored ultrasonic techniques as measures of mechanical properties of stone.

- o Measured water movement through porous limestone and explored the use of nuclear magnetic resonance to determine moisture in rock.

- o Assessed surface damage of bronze statues by ultrasonics, and testing of eddy current techniques for this application.

8. Control Technology

- o Demonstrated the ability of a commercial-scale spray-dryer/fabric filter flue-gas cleaning system to achieve over 90% SO_2 removal with high sulfur coal.

- o Quantified the SO_2 reduction potential of coal cleaning in the Ohio-Indiana-Illinois region.

- o Performed the most detailed analyses to date of flue gas desulfurization system availability.

- o Performed a comprehensive systems analyses of air pollution control options for industrial boilers.

- o Developed a greatly improved understanding of mechanisms available for combined SO_x/NO_x control in aqueous scrubbers.

9. Integrated Assessments

- Derived the basic assessment framework and operational plan for 1985, 1987, and 1989 assessments for the NAPAP.
- Produced a plan and advanced methods for integrated assessments.
- Provided an economic analysis framework.
- Provided a data coordination plan.
- Set up a central data access facility.
- Provided a research project inventory system.
- Developed a cross-sectional analysis of crop yields to deduce acid deposition and ozone impacts.
- Evaluated the importance of local and urban source to wet deposition.
- Conducted analysis of long and short-term trends in northeastern precipitation chemistry, emissions, and air quality.
- Developed spatial statistical analysis methods.
- Surveyed effects of acid precipitation on Adirondack tourism.
- Developed methods for inventorying materials at risk to air pollution and acid deposition.
- Inventoried data bases of natural resources.
- Developed a plan for uncertainty analysis of source-receptor relationships.
- Provide central database and data coordination for NAPAP activities.
- Provided preliminary evaluation of surface water sensitivity to acidification integrating geologic and water quality data for the eastern U.S.
- Provided a qualitative assessment of the effects of acidification on aquatic biota.
- Evaluated the potential effects of acid deposition on forest nutrient cycling and biomass accumulation, in cooperation with university scientists.
- Developed model systems linking models for cost/emission for environmental control to atmospheric transport and deposition models.

KEY NEAR-TERM RESEARCH TARGETS

The National Laboratory Consortium has selected three critical research areas, for which more information is required to produce credible assessments pertaining to acid deposition. The laboratories of the NLC are able to mount comprehensive, coordinated, field research efforts that will provide a thrust of new information to clarify important issues. These research efforts will shorten the time required to make scientifically defensible assessments. The first of these has been funded for FY 1985. At the present time the other two of these programs are in the form of proposals to the agencies and are being prepared for review. It is intended that these programs will be closely coordinated with the national program.

1. Nonlinearity of Acid Precipitation Processes

a. Key atmospheric question:

On what spatial scale is the deposition of acidic, or acidifying, pollutants proportional to the emissions of sulfur and nitrogen species, particularly the oxides?

b. Specific objective:

To determine how the wet deposition of acidic and other pollutants depends on inputs to individual storms, by understanding the chemical and physical PRocessing of Emissions by Clouds and Precipitation (PRECP). This will be done through analysis of appropriate data, model development and testing, and laboratory and field studies. Relationships between pollutant releases and subsequent deposition will thus be defined.

c. Anticipated benchmarks:

- Confirm whether in-cloud processes are required to explain the acidity of precipitation.
- Determine whether there is sufficient oxidant to oxidize primary pollutants in clouds and storms.
- Determine what fraction of the material not delivered to the surface by a particular storm is eventually deposited in North America.
- Determine the importance of nonlinearity effect in the overall source-receptor relationship.

2. Air-Surface Dry Exchange

a. Key deposition question:

What are the area-averaged rates of dry deposition of atmospheric sulfur and nitrogen compounds for realistically diverse landscapes?

b. Specific objective:

To determine whether the effects of natural surface diversity, including surface irregularities, nonuniform surfaces and hilly terrain, alter dry deposition processes so that significant systematic errors are caused in estimates of regional-scale deposition computed as the sum of contributions to individual types of surfaces and surface elements. To parameterize the processes of dry deposition for a variety of airborne gaseous and particulate substances in terms of flux or deposition velocity averaged over distances of tens of kilometers of "real world" terrain.

To accomplish this goal, studies on three spatial scales are envisaged. On the 1-10 km scale, direct measurements by specially instrumented aircraft will be employed. On the 0.1 m - 1 km scale, direct sampling of natural surfaces will be used. On the truly microscale (1 μm - 1 cm), wind tunnels and chambers will be used to deal with very specific deposition questions.

c. Anticipated benchmarks:

o Evaluation of the effects of natural field surface nonuniformities on sulfur and nitrogen dry deposition, so that rates to "real world" landscapes such as sensitive watersheds can be determined accurately and compared to current estimates based on flux measurements above statistically uniform bulk surfaces.

o Description of the contributions of individual surface elements in the field to removal rates of pollutants from the atmosphere, so that the partitioning of dry deposition to components of the surface can be determined.

o Evaluation as directly as possible of particle dry deposition rates by chemical species and particle size, to lessen uncertainty and resolve scientific debate on particle dry deposition velocities.

o Description of dry deposition rates of the many airborne organic substances important in long-range transport and chemical transformation of acidifying substances whose behavior is simulated in atmospheric numerical models.

3. Watershed Research Studies

a. Key process questions:

The key questions to be addressed by this research are: (1) What are the contributions of the various biological and geochemical processes, and hydrologic pathways to the delivery and processing of acidity, alkalinity and aluminum to the aquatic system; and (2) What are the spatial and temporal variations of these processes and pathways through the terrestrial system and receiving waters?

b. Specific objective:

The objective of this research is to provide a quantitative understanding of the interactions among pollutants associated with acid deposition and those biological and geochemical processes in aquatic and terrestrial ecosystems which control the rate and extent of surface water acidification. Work will be conducted in watersheds representative of impacted systems in the Northeast and Southeast, and of unimpacted systems. A mass balance approach to watershed biogeochemistry will focus on the manipulation of aquatic and terrestrial subsystems to test hypotheses concerning system responses to changes in acid deposition rates.

c. Anticipated benchmarks:

- Development of a theoretical framework for explaining acidification of surface waters by acid deposition into forested watersheds.
- Description of interactions of soil and sediment chemistry and microbial processes which regulate solution concentrations of S, N, P, and Al.
- Description of hydrologic processes and soil-water chemical kinetics which result in the discharge of water, which is not in chemical equilibrium with soils, from the terrestrial system to streams and lakes.
- Description of the role of terrestrial and aquatic biological processes in contributing to the regulation of lake alkalinity and processing of sulfur and nitrogen.

Senator **Ford**. Thank you very much, Dr. Manowitz.

I have a set of questions, and in order to maybe preserve some time and to get through today, I'm not sure we're going to, I'd like to submit to each of you three these questions and then ask that in a reasonable period of time to answer them. I would appreciate it very much.

Doctor, do you have a copy of Mr. Kasper's statement today handy?

Dr. **Manowitz**. No, I do not.

Senator **Ford**. Doctor, would you slip him one down there?

[Dr. Kasper hands statement to Dr. Manowitz.]

Senator **Ford**. This cooperation is wonderful.

Turn to page 2, No. 1. Read that statement and see if you agree with it.

[The witness complies.]

Dr. **Manowitz**. In general I agree with the statement, and what I recommend is that you referred to a hearing that took place on March 22, of Mr. Waxman's House Committee on Energy and Environment where this issue was discussed both between the National Academy and the National Laboratory Consortium, and the areas of agreement and disagreement were clearly defined.

Senator **Ford**. Do I understand that in order to reduce 20 percent, that means you have to reduce everything by 20 percent, and if you're going to reduce it by 40 percent, you have to reduce everything by 40 percent?

After you take one little place and reduce it 20 percent and expect an area some place else to be reduced by 20 percent.

Dr. **Manowitz**. My understanding of the National Academy approach is that if, indeed, you were to reduce the emissions uniformly from whatever State, except at the first point of comparison, then you would expect a uniform reduction in deposition over that same large area averaged over a period of a year.

I think the Academy report will state that if you do not reduce—if the reduction is nonuniform, then there's no statement in the Academy report that predicts what the deposition reduction would be.

Perhaps Dr. Kasper would care to——

Senator **Ford**. Do you agree with what the Doctor just said?

Dr. **Kasper**. Yes, that's a correct——

Senator **Ford**. So it has to be everywhere in order to get to average 20 percent and it has to be uniformity if you're going to get 40 percent?

Dr. **Kasper**. No.

Senator **Ford**. Let me ask you this question: 20 percent in the Midwest would not result in 20 percent in the Northeast?

Dr. **Kasper**. The report cannot say. The only thing the report says is if you reduce 20 percent throughout eastern North America you will reduce by 20 percent the deposition throughout eastern North America.

Senator **Ford**. Well, let me ask you then, does it mean that a 20-percent reduction in the Midwest will give a 20-percent reduction in the Northeast?

Dr. **Kasper**. You cannot read the report to say that.

Senator **Ford**. Fine. So what you're saying is no.

Dr. **Kasper**. That's correct, there——

Senator **Ford**. That's—stop, whoa, whoa, that's good enough.

[Laughter.]

Senator **Ford**. That's good enough. God bless you.

[Laughter.]

Senator **Ford**. The point I've made here, and I'm not trying to be facetious, I think the coal industry wants this off their back, and others, as bad as anybody. I think we are given the responsibility of trying to determine what we glean from scientific evidence, and the scientific evidence is somewhat at 180 degrees from one other. There are some areas in which they agree.

I have feared all along that we would make a decision before we knew the crux of the problem; solving the problem before we knew exactly what caused it.

I think what we are seeing now is evidence that you cannot say exactly what causes it. I hear about heat, and if you have a cool August things are going to be fine, if you have a hot August they're going to be bad. And how in the world are we going to control what the Lord does? We're not going to do it.

So I would be very hopeful that we could come to a consensus that, yes, we want to find as many answers as we possibly can before we mandate approximately $700 million annually on one State—my State, Kentucky, that within a 6-year period, reduced 500 thousand tons of emissions, and gets no credit under pending legislation, You know, there's no way for us to get any credit. And then we lose 60,000 jobs approximately. And that's a pretty tough blow to any region of this country.

And I want to find the problem. And I am still convinced, and I have never—I've seen maybe a glimmer that if we were to use the Synfuels Corp. and go to new sources of energy and new processes that we could have clean use of coal, and we would eliminate that problem. We could use the resources we have and we wouldn't be so worried about storing all the oil and be concerned about embargo and cleaning up the atmosphere, if there is a problem from coal.

There are lots of things we could do that I think would give us the answers that those of us who want to clean up the atmosphere really, sincerely want to do.

I'm a culprit, you know, to those who want to go hard. Well, I'm going to continue to be a culprit until we find some answers.

We will reconvene at 2:30 and the chairman will be here at that time.

Thank you all so very much for your patience.

[Whereupon, at 1 p.m., the committee recessed, to reconvene at 2:30 p.m.]

[Subsequently the following questions were submitted to Dr. Bernabo, Dr. Kasper, and Dr. Manowitz; the answers appear in appendix F.]

JAMES A. McCLURE, IDAHO, CHAIRMAN

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United States Senate

COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

Dr. Christopher Bernabo
Executive Director
Interagency Task Force on Acid Precipitation
722 Jackson Place
Washington, D.C. 20006

Dear Dr. Bernabo:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Dr. Christopher Bernabo
by the Committee on Energy and Natural Resources

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

1. In your September, 1983 testimony before the House Committee on Science and Technology, you stated that "[I]t is not yet possible to identify the specific change in the acid deposition patterns that would result from a given change in precursor emissions." (p. 3)

   Does this statement remain accurate today?

   Does this mean that we are still not sure that reducing sulfur dioxide emissions in the Midwest by 50% will reduce acid deposition in New England by 50% or by nearly 50%?

2. In that same testimony you reported that during FY'82 the National Program completed a preliminary study of emission sources which suggested that "nearby petroleum combustion, as well as local and distant coal combustion, could significantly affect local acid deposition." (p. 5)

   Did you study mobile sources (cars, trucks and buses) as well as stationary sources?

   Did this study suggest that local petroleum and coal combustion could be causing some of the acid deposition that is being popularly attributed to distant coal combustion?

3. The recent (December, 1983) final report of the Ad Hoc Committee to Review the National Acid Precipitation Assessment Program (NAPAP) suggests that more Federal funding of your Task Force will be required if you are to achieve your statutory objectives in a timely fashion (1985, 1987 and 1989 milestones). Do you agree with the Ad Hoc Committee's report?

4. Let's assume that we in the Congress intended to make public policy regarding any new emissions standards only after we have received sufficient scientific information to assure that any new program we enact is likely to achieve its stated objectives in acid deposition reduction in sensitive areas, rather than in emissions reductions. When will we have sufficient scientific information to make such sound public policy judgments?

Questions Submitted to Dr. Bernabo (continued)

5. What do we know with some scientific assurance about the causes of acid deposition?

6. What is the relative contribution of man-made versus natural sources of acid deposition?

7. What is the relative contribution of wet versus dry acid deposition?

8. What is the relative importance of local versus distant pollution sources in controlling the acidity of deposition at a given location?

9. What is the temporal and spatial distribution of acid deposition?

10. Is there any indication that acid deposition is accelerating? In other words, are we attempting to deal with an emergency situation?

11. Why is knowing the relationship between emissions and deposition important to the implementation of an acid deposition control program?

12. Is the theory of linearity a proven hypothesis? Do we know whether any of the atmospheric processes involved with acid deposition are non-linear? What is the significance of the linearity debate in acid rain emissions control policy terms?

13. What are the direct and delayed response theories? Do we know whether or not acid deposition has reached such proportions in sensitive ecosystems that equilibrium has been reached? What are the postulated consequences of acid deposition on poorly buffered soils versus well buffered soils?

14. How long might it take before the Interagency Task Force research efforts on acid precipitation might provide some substantive results upon which policy decision pertaining to acid rain control might be made?

15. Do we know what changes in deposition would result from a given change in sulfur oxides (or primary sulfate), nitrogen oxides, and/or organic emissions?

16. How will the research the Interagency Task Force is presently doing to monitor trends and interpret historical data relating to acid deposition and the nature of this phenomenon help in policy decisions on how to deal with this problem?

Questions Submitted to Dr. Bernabo (continued)

17. Why is understanding the rate of change as it pertains to the acidification of terrestrial or aquatic ecosystems important? How would a greater understanding of the rate of change affect our ability to do something about the problem?

18. If SO_2 emissions were reduced by 10 million tons in the Midwest, do we know whether or not that reduction would in any way affect the mechanisms of action of acid deposition on forest growth? If, as your statement suggests, the problem is from combined pollutant effects on foilage, or even soil mediated processes, could the control of just one possible causitive factor such as SO_2 in any way exacerbate damage from any other possible chemical or non-chemical factor, such as ozone, for example?

19. Why is understanding the mechanisms of acid deposition and quantitatively evaluating the processes involved important to the implementation of an acid deposition control program?

20. What do we know with some scientific certainty about the effects of acid deposition on aquatic resources, crops, soils, forests, materals, or human health? What are the scientific uncertainties or theories in disagreement in these areas?

21. What will be gained from the National Lake Survey?

Questions Submitted to Dr. Christopher Bernabo
by the Committee on Energy and Natural Resources

on behalf of Senator Ford

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

22. I am intrigued by the Task Force finding in FY'82 that local petroleum combustion could significantly affect local acid deposition. Were you able to quantify the contribution of local petroleum combustion (such as from automobiles, utility boilers and industrial uses) to local acid deposition?

If we cannot quantify the contribution of local petroleum combustion, then is it also true that we cannot quantify the contribution of distant and local coal combustion to acid deposition as well?

23. Most of the recent concerns over acid deposition and emissions has focused on the acidification of certain lakes in the Adirondack Mountains of New York. However, in your September 13, 1983 testimony before the House Science and Technology Committee, you stated: "At present, the extent of actual aquatic damages is not well established. The question of long-term trends in freshwater acidification also remains uncertain."

Will the National Program be able to establish both the actual aquatic damage attributable to acid deposition and the trend in freshwater acidification and its causes? When?

24. The Ad Hoc Committee to Review the National Acid Precipitation Assessment Program (NAPAP) filed its report in December, 1983. That report included a number of recommendations for improving the program. Are these recommendations being implemented?

25. One of the harshest criticisms of the Ad Hoc Committee was the funding levels requested by the Administration. Did you bring the funding level criticisms to the attention of the proper officials, including the OMB? Will the Administration request the increased funding recommended by the Committee?

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United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

Dr. Raphael Kasper
Executive Director
Commission on Physical Sciences,
Mathematics, and Resources
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Dear Dr. Kasper:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Dr. Raphael Kasper
by the Committee on Energy and Natural Resources

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

1. Did the National Academy report conclude that a 50% reduction in sulfur dioxide emissions in the Midwest would result in a 50% or nearly 50% reduction in acid deposition in the northeast United States?

2. Is this conclusion different from the conclusion of the 1981 Academy report? If so, on the basis of what new scientific evidence was this different conclusion reached?

3. Did the National Academy conclude that acid precursor emissions closer to the sensitive areas of the eastern United States will have a greater impact on acid deposition in those areas than will distant precursor emissions? If not, can we yet reach a scientific conclusion on this fundamental issue?

Questions Submitted to Dr. Raphael Kasper by the Committee on Energy and Natural Resources

on behalf of Senator Ford

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

4. The National Academy 1983 report contains a statement that "there is no strong evidence for a strong nonlinearity in the relationships between long-term average emissions and depositions in eastern North America." (p. 139) In English, does this mean that the National Academy has concluded that there is a one-to-one relationship between the amount of acid precursors emitted and the amount of acid deposition?

5. In an August 30, 1983 letter from Mr. Manowitz to Representatives Fuqua, Scheuer and Lloyd, the National Laboratory Consortium had this to say about the NAS statement:

   > "A lack of evidence for nonlinearity in the empirical data examined by the Committee is not logically equivalent to a proof of linearity."

   Is there a conflict between the NAS scientists and the NLC scientists on this important issue?

6. As I read the summary of the NAS report, the conclusions are mostly based on theoretical considerations and modeling exercises, rather than on a broad base of empirical data. Is this true? Is the empirical data now being collected? When will sufficient empirical data be available for the scientific community to verify their theoretical considerations and modeling exercises?

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United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

Dr. Bernard Manowitz
Chairman
Department of Applied Sciences
Room 179A
Brookhaven National Laboratory
Upton, New York 11973

Dear Dr. Manowitz:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Dr. Bernard Manowitz by the Committee on Energy and Natural Resources

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

1. In an August 30, 1983 letter to Representatives Fuqua, Scheuer and Lloyd critiquing the NAS study, you stated that "the overall feeling of the National Laboratory Consortium is that the Committee's report is flawed in several areas."

   Was this your own opinion or the consensus opinion of a number of scientists at the NLC? How may NLC scientists reviewed the NAS report?

2. In that letter you noted that the Chairman of the National Research Council stated in his letter transmitting the NAS study that it was the "Committee's judgment that if the emissions of sulfur dioxide from all sources in (northeastern North America) were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition."

   Your August 30th letter states that the "National Laboratory Consortium reviewers disagreed almost uniformly with the methods used to reach this conclusion and with the conclusion itself."

   Does your August 30th statement continue to reflect accurately the opinion of the NLC reviewers on this point?

3. Do you believe and is it the consensus of the NLC scientists that sufficient scientific evidence is not yet available to assure that a 10 million ton reduction of sulfur dioxide emissions in the Midwestern United States will result in a 10 million ton reduction of acid deposition in the Northeastern United States?

Questions Submitted to Dr. Bernard Manowitz
by the Committee on Energy and Natural Resources

on behalf of Senator Ford

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

4. If our objective is to reduce the occurrence of acid deposition in New England, do we have enough scientific knowledge today to design an acid precursor emission reduction program for the Midwest that will assure an equal reduction in acid deposition in New England?

5. Can we yet quantify the contributions to acid deposition in an area that are made by distant and near coal combustion emissions and distant and near petroleum combustion emissions, including emissions from automobiles, trucks and buses?

6. Do we understand each link in the chain of chemical events between the emission of an acid precursor and the occurrence of acid deposition in a specific region? Do we understand why acid deposition seems to occur in some areas, but not in others? Do we know the atmospheric conditions and chemical agents that must be present for acid precursor gases to result in acid deposition?

AFTERNOON SESSION

Senator **Warner** [presiding]. The committee will return to session.

STATEMENT OF HON. JOHN W. WARNER, A U.S. SENATOR FROM THE STATE OF VIRGINIA

Senator **Warner**. I commend Senator McClure for calling this hearing to examine the acid rain question and to allow the administration, recognized experts, organizations, and concerned people to testify here today. We are all aware that legislation has been proposed that will require 31 States to reduce their coal-fired electric utility SO_2 emissions by 10 million tons per year over the next 10 years. It has also been proposed that a cap be set on SO_2 emissions within those same States; the cap being that no major SO_2 source can increase its emissions over actual 1980 operating values.

America's national security is integrally tied to our energy security.

I came to the Senate Energy and Natural Resources Committee with the intention to strengthen our national security, as well as our independence from foreign countries' energy supplies by advocating policies which would maximize the utilization of this country's domestic energy resources.

The United States is blessed with a vast supply of coal. In fact, America has the largest coal reserves in the free world. We have one-third of the worlds's coal resources, representing 90 percent of U.S. energy resources. This most abundant resource has the potential to strengthen not only our energy security, but also that of the free world countries. Accordingly, while in the Senate, I have sponsored and supported policies which would increase American coal consumption both domestically and internationally.

In advocating policies to maximize energy production, one must weigh very carefully the effects of these policies on our environment.

I strongly believe that a balance can and must be struck between that of strengthening our national security, our energy security, and our economic security with that of protecting our environment.

The problem of acid precipitation has concerned me greatly as the suggested legislative solutions may impact heavily on the balance I am seeking between energy security and an improved environment.

At the time I came to the Senate, there was little concrete information to be found on the cause and effect of acid precipitation.

Reports of the effect of acid precipitation of fish wildlife, and the entire ecosystem, galvanized me to seek additional information on this problem, and attempt to resolve it. As an avid trout fisherman, I have maintained a personal interest in this problem, along with my professtional interest as a Virginia Senator.

Thus, I supported the Acid Precipitation Act of 1980, which created a major Federal research program to provide Congress with information and possible solutions to the problem.

Subsequently, I have followed very closely and the implementation of this act.

After reading numerous contradictory studies and meeting with experts on all sides of this issue, I have come to the conclusion that there is still not enough "concrete" information available for Congress to approve drastic acid precipitation legislative "cures" like some being currently debated before Congress.

In order to acquire the concrete information I feel is needed, I cosponsored Senator Byrd's bill, S. 454, to strengthen and speed the ongoing acid rain research effort. S. 454 also would provide funding to mitigate the effects of acid rain on affected water bodies and help endangered fish life.

The Subcommittee on Energy and Mineral Resources which I have the honor to chair, held hearings last Congress during which improved coal technology methods were outlined which could allow coal to be burned in an environmentally sound manner. Subsequently, I cosponsored S. 1925, which would accelerate the development and commercialization of these coal technologies.

President Reagan, in his state of the Union address to Congress in January of this year, recognized that information on the causes and cures of acid precipitation was woefully inadequate, and pledged a research program that doubled current funding to develop new technologies to reduce pollution that causes acid rain, and to restore our lakes, I applaud his sensitivity to this significant problem and support his proposed initiatives.

Whatever action Congress takes to correct this problem must be based on hard, irrefutable evidence—evidence which is not present today. Moreover, congressional action must not impair our national security, which includes our energy and economic security, nor should it impose unnecessary costs, burdens and hardships upon the public.

In attempting to resolve the problem of acid precipitation, once all the facts are in, I believe Congress must seek a balanced policy allowing the affected parties maximum flexibility to cure the problem. I believe certain proposed solutions currently before this Congress are not only premature, but also arbitrary and rigid. We do not have adequate information on their effect, and therefore these proposals should be discarded in favor of those proposed by the President, and the distinguished minority leader.

We will now have on the committee schedule panel 4, entitled "Individual Experts."

Dr. Jerald L. Schnoor, Civil and Environmental Engineering Program, University of Iowa; Dr. Ralph M. Perhac, deputy director, Energy and Environmental Division, Electric Power Research Institute, Palo Alto, CA; Dr. Dale Johnson, Environmental Science Division, Oak Ridge National Laboratory, Oak Ridge, TN; Dr. Harry G. Enoch, director, Division of Technology, Kentucky Energy Cabinet, Lexington, KY.

Would those witnesses come forward.

We will first hear from Dr. Schnoor testifying to aquatic effects.

STATEMENT OF DR. JERALD L. SCHNOOR, PROFESSOR OF ENVIRONMENTAL ENGINEERING, UNIVERSITY OF IOWA

Dr. SCHNOOR. Mr. Chairman, I'm happy to tell you that we have made some progress since your last hearings on the scope of the aquatic effects problem; namely, the number and the aerial extent of acid lakes.

I refer you in the first part of my testimony, to my written testimony, a table at the end of that testimony.

Senator WARNER. Without objection.

Dr. SCHNOOR. There exists a significant number of sensitive lakes in the United States, in the Northeast, upper Midwest, Southeast, and mountainous regions of our country.

Of those, according to this table, approximately 300 lakes which have been sampled are quite acidic, less than a pH of 5. And this is out of a total number of 4,000 lakes sampled, and a total number of maybe 18,000 lakes in the regions where these acidic lakes have been determined.

These lakes lie in sensitive areas of the Adirondack Park of upstate New York, New England, and the Upper Peninsula of Michigan, which is perhaps the first testimony in that regard, where the pH of precipitation in these regions is less than 4.6, and sulfite deposition is substantial.

These lakes represent only about 0.3 percent of the surface area of lakes in the regions of interest. And most of the acid lakes are in the Adirondack Mountains of New York.

Most scientists would agree that these lakes have been acidified at least in part by acidic deposition for the following reasons:

No. 1. Generally, in sensitive regions where we find significantly acidic precipitation—I'm defining that as pH less than 4.6—we find some acid lakes—lakes defined as less than pH 5. Where we do not find acid rain, we do not find acid lakes.

No. 2. Sulfate from SO_x emissions is a dominant anion in precipitation in these regions, and in the lakes. There exist strong correlations between sulfate in precipitation and sulfate in the lakes, and this is similar to correlations reported for acid lakes in Scandinavia and other locations.

No. 3. Hydrologically, we know that there exists some acid lakes in which 90 percent or more of their water comes from precipitation falling directly on the surface of the lake. The chemistry of these lakes is greatly influenced by the chemistry of precipitation. Land use and forest precipitation are minimal in these cases.

No. 4. We know that lakes do respond to changes in sulfate and acid loading. What's more, the process is not completely irreversible. Lakes near the smelter at Sudbury, ON, and the LaCloche mountain lakes, about 70 kilometers south of the smelter, were acidified over a relatively short period, on the order of ten years. Recent measurements on these lakes have indicated a significant decrease in acidity since emissions and acid deposition from the smelter have decreased.

No. 5. Based on research at a few calibrated watersheds in sensitive areas of the Adirondacks, the Hubbard Brooke Forest, a watershed in New Hampshire, lakes in the Dorsett area of Ontario, and seepage lakes in northcentral Wisconsin, we know that some 50 to 100 percent of the total acid inputs to these lake watersheds is due to the acidity of precipitation.

I suspect that the situation is not going to further deteriorate unless acidic deposition increases. Most extremely sensitive lakes have already responded to historical increases in acid rain.

Future changes at our constant acidic deposition levels of today would occur only over geologic time.

In summary, I would say that there are many good reasons to reduce SO_x emissions. The acidification of lakes is not the most compelling reason.

A small percentage of our lake resource has been affected and much of the damage, while not being totally irreversible, has already occurred.

Other water quality problems in lakes, such as eutrophication and toxic chemicals, impair use on a far greater percentage of the total resource.

However, sulfur oxide emissions do contribute to materials corrosion, human health problems, as you know, diminished visibility, potential air pollution effects on crops and forests, and, perhaps difficulties in our relationships with Canada.

The only new things that I guess I have to tell you today, and to summarize, is that we do have a little bit of a better estimate on the scope of the problem as alluded to this morning. There are acid lakes. They're few in number and little in area, but they exist as far west as the State of Michigan. And, in my professional opinion, most of the damage has already occurred. The situation is not going to further deteriorate, and the damage to the lakes is most probably reversible.

Thank you.

[The prepared statement of Dr. Schnoor follows:]

Statement of

Jerald L. Schnoor

Professor of Environmental Engineering

University of Iowa

Before the

Senate Committee on Energy and

Natural Resources

April 30, 1984

Mr. Chairman, Members of the Subcommittee:

By way of introduction, I am principal investigator of two research grants for EPA. One is to study factors controlling lake acidity in northcentral Wisconsin and the Upper Peninsula of Michigan, and a second is to assess the lake resources-at-risk due to acidic deposition in the Adirondack Park and New England. I am editor of a book on the mathematical modeling of "acid rain", author and co-author of five articles on the subject, and a member of the recently appointed National Research Council Panel on Lake Acidification Processes. From work in the U.S. and Switzerland, I have developed a mathematical model to estimate the change in acidity of a lake based on the acid deposition in its watershed.

My subject is acid rain and, particularly, the acidification of aquatic resources. I do not believe that this problem is nearly so large as some have suggested, nor so small as others have chosen to neglect it. I do believe that there has been substantial progress in understanding the acidification of lakes and streams. While I do not claim that the scientific community is in total agreement nor that it knows everything there is to know about acid rain and acid lakes, I do suggest that the future holds diminishing returns in terms of new knowledge and that we may know enough to make some decisions right now.

In this statement, I will speak to four points:

1) What do we know?

2) What do we suspect?

3) What information is lacking?

4) And what should we do?

First, what do we know? We know that there are sensitive surface waters in the United States based on measurements of their alkalinity concentrations (acid neutralizing capacity). These sensitive lakes and streams are extensive in number (thousands of lakes) and widespread including the northeast, upper midwest, southeast, and mountainous west regions of our country. Sensitive lakes tend to be rather small, usually less than 50 hectares (124 acres), and sensitive streams are small or high in elevation.

We know that coal combustion and sulfur emissions have increased over the last thirty years and since the turn of the century.

We know one fact that seems to me to be rather telling. For the Northeast and Upper Midwest, where we find precipitation that is significantly acid (volume weighted average $pH < 4.8$), we also find acid lakes with pH less than 5.0. Where precipitation measurements are not so acid, acid lakes have not been reported. For examples, one can follow a precipitation acidity gradient through the Upper Midwest. In northeastern Minnesota and the Boundary Waters

Canoe Area, the acidity of precipitation is relatively small (pH ranging from 5.0 in the west to 4.8 in the east), and in an EPA and University of Minnesota-Duluth survey of some 266 lakes, there were no acidic lakes (defined as lakes with pH less than 5.0). Moving eastward to northcentral Wisconsin, precipitation becomes more acidic (pH 4.6-4.8), and in an EPA and Wisconsin Department of Natural Resources survey of 275 lakes, there were two acid lakes reported. Moving further east to the eastern end of the Upper Peninsula of Michigan where the acidity of precipitation is still greater (pH 4.3-4.5), there were 6 out of 53 lakes with pH below 5.0. The number and the percentage of acid lakes increases dramatically across the depositional gradient. In the Upper Peninsula of Michigan, there are a number of other acid lakes that have been reported by the U.S. Forest Service in National Forests.

There exists a correlation between the sulfate concentration in lakes and the pH and sulfate concentration of precipitation. This is similar to correlations reported for lakes in Norway and Sweden. Sulfate is the dominant anion in the chemistry of the acidified lakes.

Only a fraction (10-20%) of lakes in the Northeast and Uppper Midwest have been reliably sampled to date. Thus it is necessary to extrapolate our findings from synoptic surveys if we are to draw conclusions regarding the total number of lakes at risk. Currently, we know that there are approximately 150-200 lakes in the Adirondack Park of New York that are quite acidic. About 700 lakes have been adequately sampled out of a total 2,877. For New England, about 15 acid lakes have been determined out of perhaps 2200 low alkalinity lakes. There exists a population of 7000 lakes greater than six hectares in surface area and a total number of lakes greater than 10,000 in New England.

We know that lakes do respond to changes in sulfate and acid loading. What's more, the process is not completely irreversible. Lakes near the smelter at Sudbury, Ontario, and the LaCloche mountain lakes (about 70 km southwest of the smelter) were acidified over a relatively short period of time, on the order of 10 years. Recent measurements on these lakes have indicated a decrease in acidity since emissions and acid deposition from the smelter have decreased.

Finally, we know that there are at least two types of sensitive lakes. Within a sensitive geologic (mineralogic) area, there are differences in lake watershed and hydrologic characteristics. Lakes with a "flashy" hydrograph, where rain water or snowmelt water moves quickly through shallow or frozen soils to reach the lake, tend to be very sensitive to acid inputs. These lakes often have coarse and sandy soils, with crystalline bedrock at shallow depth, rather steep slopes within the watershed, and a large surface area to watershed area ratio. The second type of hydrologic sensitivity is that of seepage lakes. These are especially prevalent in the Upper Midwest where approximately 50% of the lakes sampled were classified as seepage lakes. These lakes have no inlets or outlets; they receive most of their water from direct precipitation onto the surface of the lake, and most of their outflow is seepage to groundwater. A few lakes under intensive ivestigation in north-central Wisconsin show that as much as 90% of the water in the lake comes from precipitation falling directly onto the surface of the lake. Thus, the chemistry of these lakes tends to be similar to precipitation chemistry. I point out the notion of hydrologic sensitivity because it is one of the characteristics that we, at the University of Iowa, are using to estimate the total number and areal percentage of lakes that may be at risk (or that have previously been acidified) due to acid rain. Maps are used extensively in the effort.

The results of research to date do not unequivocably prove that lakes have been acidified by anthropogenic acid precipitation. Historical data is not extensive nor entirely conclusive. But several lines of reasoning infer that lake acidification has occurred, including: 1) the discovery of acid lakes only where there is significantly acidic precipitation across the depositional gradient; 2) the correlation between sulfate in precipitation and sulfate in lakes; 3) the presence of acidic seepage lakes which receive most of their water directly from precipitation on the surface of the lake; and 4) the results of input/output budgets on calibrated watersheds and mass balance model calculations which show that acid precipitation accounts for 50-100% of the total acid sources in the watesheds of sensitive lakes.

What do we suspect? More correctly, on what can most scientists agree? It is likely that a number of sensitive lakes have become acid due, at least in part, to acidic deposition. The number of lakes that have been acidified is bounded by the number of acid lakes that exist and have been measured. Based on the numbers previously given, there have been 1000-2000 lakes sampled that were quite acidic, mostly in the Adirondack Park. If about 10-20% of the total resource has been sampled, we might expect that 1000-2000 acid lakes presently exist. Acid lakes would account for a very small percentage of the total surface area in lakes (< 0.1%). I believe that these lakes owe their acidity, in part, to anthropogenic acidic deposition. There are other sources of acidity in watersheds including effects of forest and humus production and accumulation, oxidation reactions (of carbon, nitrogen, and sulfur), and certain ion exchange reactions in soil. But in the few cases where careful budgets have been performed, the input of acidity from acid precipitation was at least 50% of the total acid inputs to the system.

Secondly, I suspect that the situation is not going to further deteriorate unless acidic deposition increases. The damage has already occurred. Most extremely sensitive lakes have already responded to historical increases in acid rain. They have responded over a period of 5-20 years, based on the average residence time of water in a given lake. There still exist plenty of minerals in the soil to continue to supply bases for partial neutralization of future incident acid precipitation. Any future changes (with constant acidic deposition) would occur over geologic time. It is conceivable that some lake watersheds could deplete their sulfate adsorption capacity in the soil and become acidic, though this has not been demonstrated to date.

I also suspect that there are a considerable number of lakes that are "acid-stressed", but not classified as acidic. These lakes would be susceptible to shock episodes of pH decline during storms or snowmelt events. They might also contain relatively high concentrations of heavy metals (lead, mercury, cadmium, and zinc) from fossil fuel combustion, and they might have a rather low biological diversity. Extreme events could cause a stressed fish population or other biotic component to die-out.

What is lacking? Trend information. It is difficult to know where we are going if we do not know where we have been. It is exceedingly difficult to find longitudinal data sets for emissions, precipitation pH, lake pH, plankton or fish resources that are untroubled by sampling or analytical problems. However, there are numerous reports around Sudbury, Ontario, and in Scandanavia of the acidification of lakes. In the U.S., all the pieces of the puzzle do not necessarily fit; fish data are complicated by overfishing and fisheries management; water chemistry data are haunted by differences in analytical methods. Nothing is "clean", but the evidence, when taken *in toto*, is rather convincing.

We are lacking quantitative source-receptor relationships. We do not have a proven methodology to calculate the resources at risk, e.g. the percent of lakes which will become acidified to a specified level within a region at a specified loading rate. We cannot afford to protect the most sensitive lakes in the ecosphere, so we must include the quantity of the resources at risk in our decision making.

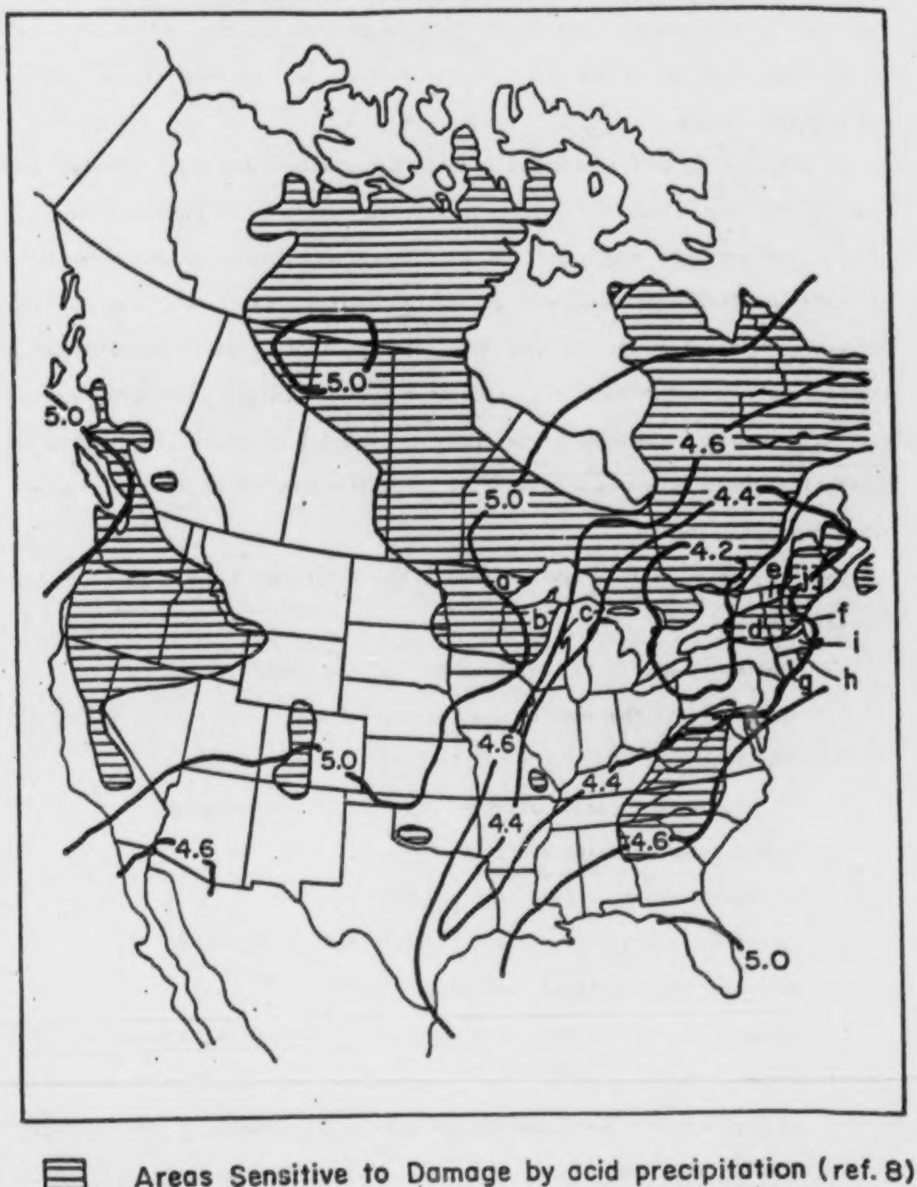
We are lacking verification of kinetic formulations and rate constants for some of the most important processes in that "acid rain" picture. In particular, uncertainty regarding the kinetics of oxidation in the atmosphere prevents us from answering the deceptively simple question, "What is the percentage reduction in hydrogen ion deposition at a given receptor as a result of a two-fold reduction in emissions at the source"? Similarly we lack the rate constants for some terrestrial and aquatic processes. e.g. chemical weathering, which provides a measure of homeostasis in the ecosystem as acidic deposition increases.

What should we do? I would propose the following actions based on our present state:

1) Laboratory and field research to fill the gaps, especially in the area of chemical kinetics.
2) The linkage of atmosphere and terrestrial/aquatic models in order to quantitatively answer source-receptor questions of emission controls.
3) A targeted emission reduction program to reduce SO_x in a specific region with monitoring and research to determine the costs and benefits.

In summary, there are many good reasons to reduce SO_x emissions. The acidification of lakes is not the most compelling reason. A small percentage of our lake resource has been affected and much of the damage, while not being totally irreversible, has already occurred. Other water quality problems in lakes, e.g. eutrophication and toxic chemicals, impair use on a far greater percentage of the resource. However, sulfur oxide emissions do contribute to materials corrosion, human health problems (notably emphysema and asthma), diminished visibility, potential air pollution effects on crops and forests, and difficulties in our relationships with Canada.

Figure 1. Map showing areas sensitive to damage by acidic deposition, annual volume weighted average pH of precipitation, and locations of acid lakes (a = northeastern Minnesota, b = northcentral Wisconsin, c = eastern U.P. Michigan, d = Adirondack Park, e = Vermont, f = New Hampshire, g = Connecticut, h = Rhode Island, i = Massachusetts, j = Maine).



▤ Areas Sensitive to Damage by acid precipitation (ref. 8)

—5.0— Isopleths for annual volume weighted average pH of precipitation, 1979 National Acid Deposition Program

Table I. Number and Areal Extent of Acid Lakes

	No. of Acid Lakes with pH < 5.0	No. of Lakes Sampled	Total Number Of Lakes in the Region	Surface Area of Acid Lakes (pH < 5) ha	Total Surface Area of Lakes in the Region, ha	Refs.
Minnesota (N.E.)	0	266	2,200	0	~100,000	2
Wisconsin (N.C.)	2	275	1,600	36	81,000	2
Michigan (U.P.)	6	53	900	150	~25,000	3
Adirondacks	189	714	2,877	3,000	114,000	4,5,7
Vermont	12	283	525	~150	88,000	6,7
New Hampshire	21	500	1,000	~200	74,000	6,7
Connecticut	1	286	1,500	3	38,000	6,7
Rhode Island	8	91	1,500	~100	41,000	6,7
Massachusetts	8	644	1,500	~50	120,000	6,7
Maine	19	749	4,000	~100	590,000	6,7
Totals	266	3,861	17,602	3,789 (0.3% of total)	1,271,000	

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Senator **Warner**. That leads me to my first question. On the 19th of August, 1982, in this hearing room, this committee received testimony that suggested that the acidity of lakes in the Northeast had not increased, and, in some instances, had even decreased since the 1960's.

Once again, what is your view of the statistics and the facts relating to the acidity, is it on the increase, decrease, or level?

Dr. **Schnoor**. I have not worked with the longitudinal data sets. What I report to you today, to clarify, is the present status. However, in my opinion with regards to that question, I think that the lakes—if the acid deposition continues to remain roughly constant, as we believe it is, then the lakes—what you see is what you get. The present damage can be monitored now, and it's not changing.

Senator **Warner**. It's about level. But there is hope and it can be reversed?

Dr. **Schnoor**. I believe so.

Senator **Warner**. In a positive way?

Dr. **Schnoor**. Yes.

Senator **Warner**. What is the pH of unpolluted rain?

Dr. **Schnoor**. If there's such a thing as unpolluted rain over the continental United States, we say that the water falling through a clean atmosphere in the equilibrium with carbon dioxide would be pH 5.65.

Senator **Warner**. Are there any studies which would indicate otherwise?

Dr. **Schnoor**. There have been studies, not by myself, but by others in island environments in the South Pacific and elsewhere, to try to get a handle on what could be the pH in remote regions.

Senator **Warner**. Well, what we're trying to determine is sort of a base of fact; and that is, are there any scientific studies which find the natural pH of rain is somewhere between pH 3.6 to pH 5?

Dr. **Schnoor**. Not that I'm aware.

Senator **Warner**. Can lake liming and other such programs, short of significant new emissions control, protect sensitive lakes from acidification?

Dr. **Schnoor**. Lake liming can help maintain the pH of a lake high, which could possibly improve their chances of a reproductive fishery. But I'm told by my ecologist friends and colleagues that there are other damages, more subtle damages that would occur.

[Subsequently, the following questions were submitted for the record:]

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United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

Dr. Jerald T. Schnoor
Civil and Environmental Engineering Program
University of Iowa
Iowa City, Iowa 52242

Dear Dr. Schnoor:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Dr. Jerald Schnoor
by the Committee on Energy and Natural Resources

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

1. At our August 19, 1982 hearing, we received testimony that suggested that the acidity of lakes in the northeast had not increased -- and had even decreased -- since the 1960s. Do you concur that lake acidity in the northeast is not increasing significantly?

2. In your judgment, at what level of pH does a lake begin to have difficulty supporting fish and plant life?

3. What factors combine to determine the acidity of lakes?

4. In your judgment, what percentage of the lakes in our nation are in danger of acidification from acid deposition? How many of those lakes are outside the northeastern United States?

5. Can lake liming and other such programs short of significant new emissions controls protect sensitive lakes from acidification?

Senator **Warner**. Thank you very much.

We will now proceed to hear from Dr. Ralph Perhac.

STATEMENT OF DR. RALPH M. PERHAC, DIRECTOR, ENVIRONMENTAL ASSESSMENT DEPARTMENT, ELECTRIC POWER RESEARCH INSTITUTE, PALO ALTO, CA

Dr. **Perhac**. Thank you, Mr. Chairman.

For the record, I am Ralph Perhac, Director of the Environmental Assessment Department at the Electric Power Research Institute in California.

I have submitted a written testimony and a supporting document. I request respectfully that that be submitted for the record, and rather than read from that, let me take just a few minutes and reach a few key points that I think come out in my testimony.

Senator **Warner**. If I might add, you speak from a basic experience, that's the most effective way to handle this testimony. We will put your entire statement in the record.

Dr. **Perhac**. Fine. Thank you.

At the Electric Power Research Institute, we have been involved in acid deposition research for over 7 years.

In my Environmental Assessment Department alone, we have already spent about $25 million, and we anticipate spending over $70 million in the next 5 years.

I mention that just to let you know the scope of the program; that, next to the Federal Government, is by far the largest acid deposition research program of any group in the United States.

We don't carry out that research in isolation. We work very closely with a number of States, and with the Federal Government through the National Acid Precipitation Assessment Program.

In fact, I have been appointed by the President as an advisor to that program on its task force, as well as serving as an advisor to the large California program, having been appointed by the Senate.

I mention that to let you know that we are able to stay in touch with what is going on in the country so that we can coordinate our research with others to get more effective results from what we do.

Now, what have we found from this large research program? In terms of ecological effects, I would say our most significant finding relates to lake acidification, simply because we have been involved in that for the longest period of time in the Adirondacks, the area considered the most sensitive in the United States to effects from acid deposition.

Our findings there, or our principal findings are twofold. First, we find that in assessing the effects of acid deposition on a lake, one must consider the entire watershed. It is not sufficient to look at lake water or just what's coming down from the sky. The entire watershed has to be assessed.

We find, for example, that lakes, under similar geologic and rainfall conditions, can have remarkably different acidities, even though they're just a few miles apart.

We find, for example, that soils can play a very significant role, if not the major role, in what the acidity of a lake may be.

We find, even in sensitive regions like the Adirondacks, some soils can have neutralizing capacities that can last for hundreds, if not even thousands of years.

In view of these findings, we feel that we must exercise great caution in trying to estimate the extent of damage to lakes or the susceptibility of regions to lake simply by looking at geologic maps alone, or by looking at maps, say, of water alkalinities.

We feel that each watershed has to be studied in itself before we can draw some conclusion as to the susceptibility of that area or of that lake.

Our second finding has to do with the rate of ecological damage. We have a limited, but very intensive study, in this sensitive area of New York State, and we have no evidence so far that we can find any measurable damage over the next decade or so at present levels of acidic deposition.

We have already been in that area for 5 years, monitoring regularly, and we can measure no change under present conditions. And our mechanistic models indicate that under present acidity conditions, we will not be able to measure any change in the lakes there for at least the next decade or so.

That finding may have very profound implications in terms of what society wants to do with regard to regulation.

Our environmental program covers many aspects. I have mentioned just one. I won't cover the others, they're in the record.

Let me move on to one other area of research, and that's atmospheric work. Where our aim there is to gain a better understanding of the source-receptor relationship; that is, the relationship between what goes up in one place and what comes down in a different place.

It's the source-receptor relationship which the National Academy of Sciences feels is probably the key to understanding the effectiveness of any control strategy that might be promulgated either through legislation or through regulation.

We have a sizable research effort in this source-receptor relationship. About 60 percent of my budget goes toward that.

We have a good handle on what goes up, and we have good data on what's coming down, at least in terms of wet precipitation. We still lack some very key information on two critical aspects. One is cloud processes, and the other is atmospheric dynamics.

By atmospheric dynamics, I refer to the transport of pollutant from one place to another. And until we can resolve this question of atmospheric dynamics and cloud processes, we don't feel that we're in a position to improve the model sufficiently that will allow us to judge the effectiveness of any control strategy.

Let me conclude this testimony with three statements.

No. 1. Like many other scientific groups, we're well aware and we recognize the many uncertainties in our scientific knowledge. Now, whether these uncertainties are sufficient to preclude legislative or regulatory action I can't answer, because that's not a scientific issue. It involves things other than science alone.

Statement No. 2 is this: We simply do not have the scientific tools to judge the effectiveness of any control strategy that might be promulgated. It's very easy to propose something, but judging that control strategy—if it is a selective one—is something we cannot yet do. And to that extent, we agree totally with the Academy, which comes to essentially the same conclusion.

My third statement is this: In view of the first two statements, we can see where the Congress and the regulators, or the agencies, are in a very difficult position. They face a difficult question. Should they, for example, propose some sort of a control strategy which is going to cost money, but whose effectiveness cannot yet be judged for a problem which is still not well defined?

Unfortunately, science cannot give you an answer to that question, because it involves factors other than science. But we do have an active research program, it does coordinate with other agencies and with other governmental groups, and we feel confident that in time we will get better answers to the question.

Thank you very much.

[The prepared statement of Dr. Perhac follows:]

United States Senate - Energy Committee

Testimony

Ralph M. Perhac, Director
Environmental Assessment Department
Electric Power Research Institute
Palo Alto, California

April 30, 1984

Mr. Chairman, I am Dr. Ralph M. Perhac, the Director of the Environmental Assessment Department of the Electric Power Research Institute in Palo Alto, California. I also serve as a Presidential appointee to the Task Force of the National Acid Precipitation Assessment Program. Thank you for the opportunity to testify before your Committee.

Before discussing acidic deposition, I wish to say a few words about the Electric Power Research Institute, or EPRI as it is commonly known. Despite the name, we really do little research. We are a research-funding institute, and our monies go to such organizations as universities, private research groups, and national laboratories. Our charge, of course, is to support research dealing with the generation and transmission of electricity, research that may range from improved boiler design to the relation between air quality and pulmonary dysfunction. My Department focuses specifically on environmental questions. The funds to support research come from contributions based on voluntary association of both public and private utility companies. For the Institute, this support amounts to nearly $300 million for research in 1984.

We maintain a constant concern about the credibility of our work because, without credibility, we are of little use either to the industry or to society. We do a number of things to insure credibility. I will mention just two. First of all, we support no research that advocates policy or recommends legislation or regulation. We will not, for example, support a study whose goal is to recommend an ambient air-quality standard for a particular pollutant.

Secondly, we cannot exercise any control over the results of the research. For all practical purposes, the results of any study are the property of the researcher and he is free to do as he wishes with those results. He may publish or not publish, as he chooses. We do, however, strongly encourage and urge our researchers to publish findings in peer-reviewed scientific journals as well as in EPRI reports. For at least the last two years, the researchers we support in my Department have averaged well over 100 papers a year published (or accepted for publication) in scientific journals.

Enough about EPRI, let me move on to the subject of acidic deposition, a subject with which we at EPRI are not exactly unfamiliar. We have been involved heavily in acidic deposition research for over seven years. We have already spent over $25 million on such research. We expect to spend about $12.5 million this year (1984) and over $70 million—over the next five years. I can say without any hesitancy that, except for that being supported by the Federal Government, we have the largest and most comprehensive acid deposition research program of any group in the country, if not in the world.

Perhaps the major concern over acid deposition is fear that: (1) both the acidity and geographic extent of such deposition are increasing, and (2) such increases may be causing severe damage to ecosystems, specifically to forests, crops, and lakes and their fisheries. We, in the scientific community, are frustrated and plagued by the many uncertainties which face us in our attempts to assess both the nature and extent of any damage that might be attributed to acidic deposition. I won't dwell on the details of the many uncertainties in our knowledge because I am sure that you have read and heard them many times. Suffice to say:

1. We are not certain what changes in deposition may have occurred over the last few decades (Hansen and Hidy, 1982; Wisniewski and Kinsman, 1982). As pointed out in the annual report of the National Acid Precipitation Assessment Plan to the President and the Congress (NAPAP, 1982, p. 17), "Because

of the general lack of consistent monitoring in the past, long-term trends in acid deposition in North America are poorly defined."

2. We know that forests in different parts of the world show damage but, again, we are hard-pressed to relate that damage to a specific agent or to demonstrate effects that can specifically be attributed to acidic deposition. In Scandanavia, for example, "There are...no clear signs or evidence of...reduced forest production resulting from the effects of acid precipitation on Scandinavian forestland..." (SMA, 1982). Closer to home, we have "...no proof that acidic deposition is currently limiting growth of forests in...the United States." (EPA, 1983, p. 3.41). And, again, citing the NAPAP report released 10 months ago (NAPAP, 1982, p. 33), "...there is no indication to date that...forest production is being affected."
3. Similarly, with crops, we have little evidence that ambient levels of acidic deposition are affecting productivity. "The most consistent conclusion to be drawn from agricultural research at all scales and with all species has been 'no effect' at current...pH levels (pH 4.0-4.2)." (NAPAP, 1982, p. 33).
4. Finally, when we consider aquatic systems, we are well aware of the presence of acidic lakes and of lakes in which fish populations have declined but we also recognize that "Many of the reported cases that suggest that acid deposition is the cause of some observed change in an aquatic ecosystem are based on circumstantial evidence and lack documentation of the mechanisms linking cause and effect. At present, the extent of actual damages is not well established." (NAPAP, p. 1982, p.2).

Not only do we face a multitude of uncertainties when we try to evaluate the extent of damage, we face them when we try to decide what sort of specific control strategy (on emissions of oxides of sulfur and nitrogen) will result in a decrease of acidic material. If our interest is in reducing deposition uniformly over the entire eastern United States, we can almost certainly achieve that, as the National Academy of Sciences points out (NAS, 1983, p. 10) by a uniform reduction of emissions from all sources. If, however, we wish to be more selective in where we want reductions of acidic material to occur, we find that we lack the scientific knowledge to achieve our goal. We simply do not have the air-quality models which allow us to make predictions which many feel are accurate enough to be of use in deciding control strategy. After examining a number of models from both countries, a joint group of U.S. and Canadian scientists concluded (MOI, 1982, p. 11.1), "The adequacy of available models to predict the results of alternative emission patterns (i.e., the change in deposition that would result in a change in emissions) is uncertain." And the Academy scientists (NAS, 1983, p. 10) "...do not believe it is practical at this time to rely upon currently available models to distinguish among alternative strategies." As a result, they "...cannot objectively predict the consequences for deposition in ecologically sensitive areas of changing the spatial pattern of emissions in eastern North America, such as by reducing emissions in eastern North America, such as by reducing emissions in one area by a larger percentage than in other areas." (NAS, 1983, p. 11).

Yes, uncertainties in our scientific knowledge plague us but, at EPRI, we have not used these uncertainties as an excuse for inaction. As I have mentioned, we have underway a very extensive and comprehensive research program - one which we feel is well co-ordinated with the effort of the Federal Government under the National Acid Precipitation Assessment Program. In addition to this written statement, I wish to submit, as an exhibit, an EPRI report (Allan and Perhac, 1983) which describes, in detail, our acid precipitation research program.

The goal of our EPRI program is to assess the contribution of coal burning by the utility industry to any damage that might result from acidic deposition. In order to achieve this goal, we have designed a program to study: (1) the effects of acidic deposition on ecosystems, and (2) the atmospheric physics and chemistry which lead to the deposition of acidic material - emphasis being on the contribution of coal burning by utilities to the atmospheric processes. By combining (1) and (2), we hope to gain considerable insight into the role played by the utility industry in acidic deposition and its effects on the ecosystem.

Extensive research on forest systems has been underway for about two years, emphasis being not so much on damage estimates but on processes which ultimately affect forest productivity, viz., the relation between acidic deposition and nutrient cycling. Preliminary findings suggest that ambient levels of deposition have little effect on cycling in forested areas of the Southeast and especially the Pacific Northwest. More recently (within the past year), we have initiated a major, multi-million dollar aluminum biogeochemical study of forested watersheds. Among other things, this new project, which will involve research in the United States, Scandinavia, and Germany, will test the hypothesis that aluminum mobilization resulting from acidic deposition is responsible for damage to forests. Significant and definitive results from this research will not be available for at least two more years.

Crop research at EPRI has been underway for over three years. We have studied the effects of ambient levels of acidic deposition on six major agricultural crops (including two cultivars of soybean) and found no adverse effects and no interaction between acidic material and atmospheric ozone. In view of our results and the federal effort, we are shifting our emphasis from acid precipitation effects on crops to a study of mixed gaseous pollutants and crops.

Our most extensive experience has been with aquatic systems, specifically with the relation between atmospheric input of acidic material and lake acidity. Such lake studies have been underway continuously since 1977. The approach has been, and continues to be, mechanistic and process oriented. A $5-million study in the Adirondack Mountains of New York State has produced a mathematical, computerized model which serves as a means of understanding the processes that could lead to lake acidification and which allows an estimate of the effects on lake acidity of changing the atmospheric loading of, for example, sulfur oxides. Our work in the Adirondacks has demonstrated quite conclusively that:

1. The entire watershed (physical, chemical, and biological characteristics) must be considered in assessing the effects of atmospheric input on lake acidity.
2. Susceptibility of lakes to acidification in any particular region cannot be judged either by the nature of the bedrock (geology) alone or just by the alkalinity of the lake. Again, each lake's watershed must be taken into consideration.
3. Nearby lakes receiving identical atmospheric input and in areas of similar geology can have strikingly different acidities because of watershed differences.
4. The physical and chemical characteristics of soil play perhaps the major role in lake acidification.
5. Even in areas considered highly susceptible to acidification, e.g., the Adirondacks, soils in some watersheds have tremendous neutralizing capacity - capacity to neutralize ambient levels of atmospheric acids for at least hundreds of years.
6. We have no evidence from our limited (but intensive) study that measurable changes will take place over the next decade or so. Having been in the Adirondacks for over five years already, we have not been able to measure any progressive changes in lake acidity.

A major uncertainty in our lake work is the applicability of our model on a regional basis and in other parts of the United States. Additional work to resolve these unknowns is actively in progress, with support also coming from the Department of Natural Resources of Wisconsin and from the Empire State Electric Energy Research Corporation. Additional lake work and model testing are taking place in Wisconsin and the southern Appalachians.

To complement our mechanistic lake studies, we recently began a study of the relation between water chemistry and fisheries.

This research will involve modeling, bioassay work, and field studies. The fisheries research will probably yield no definitive findings for at least another three years.

Approximately 40 percent of my Department's acidic deposition budget (over the next five years) is spent on effects research. The remaining 60 percent will be used for atmospheric studies dealing with the causes of acidic deposition. The essential components of the atmospheric research are: emissions, transport (including atmospheric dynamics), cloud processes, and wet and dry deposition. Our ultimate goal is to establish reliable source receptor relations.

We have already completed one very detailed emissions inventory (for 1978); a second (1982) is in process of being developed. All our inventory work has been closely coordinated with that of the Department of Energy and the Environmental Protection Agency. Working with that coordination are the staffs from the NAPAP program.

Long-range transport modeling is an integral part of our atmospheric research. In general, we find that the uncertainty in our ability to predict deposition or ambient concentrations as a function of emissions is about 100 percent - a figure fairly typical of many regional models. A key factor in our failure to predict with a lesser uncertainty is the poor state of our knowledge about atmospheric dynamics as related to long-range transport of pollutants. Experiments such as the recently completed CAPTEX-83 (Cross Appalachian Tracer Experiment) will play an important part in improving our knowledge. That experiment, to which EPRI contributed about 35 percent of the funding (along with DOE, EPA, NOAA and Canada), demonstrated quite conclusively that long-range transport of a non-reactive pollutant does occur and that techniques for measuring minor concentrations of tracers do exist. We feel strongly that additional large-scale tracer work is needed in order to resolve the source-receptor relation as quickly as possible.

Our research into cloud processes is based on a combination of field studies and laboratory chamber investigations. Some of our most recent work (by Brookhaven National Laboratory) demonstrates that the amount of sulfur oxide in the atmosphere may not be the critical factor in the final acidity of precipitation. The presence of hydrogen peroxide can, in different instances, play a key role. Although far from complete, our research on cloud processes gives strong indication that, at least on a sub-regional basis, many of the processes leading to acidification of precipitation are probably non-linear so that a reduction in emissions would not be followed by a corresponding, and linear, reduction in deposition.

EPRI deposition studies began in 1978 with a 9-station monitoring network in the East - one which used collection techniques identical to those used by the federal MAP3S program. As a result, EPRI and MAP3S data are highly compatible and, for all practical purposes, interchangeable. We are no longer involved in routine monitoring, that function being taken over (financially) by the utility industry with EPRI acting only as the scientific project manager. The original 9-station EPRI network has been expanded by the utility industry to 20 stations, 19 of which are east of the Mississippi. We do, however, have an active program in dry deposition research.

Without a doubt, in addition to the effects uncertainties, the major uncertainty in the acid deposition issue is the relation between selective reduction of emissions and deposition - the so-called source-receptor relation. The scientists who worked on the Academy report of 1983 regard "...the problem of relating emissions from a given region to deposition in a given receptor region to be of primary importance..." (NAS, 1983, p. 141). At EPRI, we still see three major gaps in our knowledge before we are able to improve our knowledge of source-receptor relations. First, we must know the relative contribution of dry deposition to total deposition. Secondly, many questions of atmospheric dynamics need better resolution. Finally, research on cloud processes still has a long way to go. Fortunately, research in all three areas is underway and such research is needed to develop the improved models which we must have if we are to judge the efficacy of control strategies. It is ultimately through modeling that the source-receptor question will be resolved (NAS, 1983, p. 11, 145, 154). The Academy scientists recognize that many years of research and data gathering are needed before we will have realistic, validated models (NAS, 1983, p. 148-149). In the meantime, they do feel that much "...useful information...can be determined fairly quickly by direct empirical observation..." (NAS, 1983, p. 149). Large-scale, massive tracer experiments (similar to the proposed MATEX - Massive Tracer Experiment) are, in our opinion, the most feasible way of obtaining the empirical information needed to improve our modeling capabilities. We now have underway, at a cost of nearly $1 million, a study to assess the true feasibility of carrying out a massive tracer experiment in the East. And we are coordinating the feasibility effort with other interested branches in the Federal Government.

Our research (and research planning) at EPRI is not carried out "in a vacuum". We make a concerted and sincere effort to coordinate with other groups doing research on acidic deposition. For example, we are closely coordinated with the $18 million/5-year program in California, in part through my role as an advisor to that program, having been appointed by the California Senate. At the beginning of this testimony, I mentioned that I am one of the three Presidential appointees to the NAPAP Task Force. In that role, I am able to have first-hand knowledge of what the NAPAP program is doing. Many of the goals of NAPAP and EPRI are similar but, in almost every instance, our (EPRI and NAPAP) specific research programs are complementary rather than duplicative. We may be studying exactly the same thing but our approaches will be quite different. Lake acidification is a good example. The EPRI approach to the issue is principally mechanistic and process oriented. Such an approach gives little information on the extent of acidification throughout the nation. In contrast, part of the federal effort is an extensive survey to answer the question of geographic extent. The two different approaches to the same issue complement each other very well. And because EPRI and NAPAP commonly use researchers from the same organizations, we have little problem in knowing what each is doing. I could cite many examples of EPRI and NAPAP studying the identical question but through different, and complementary approaches - approaches which will yield more meaningful results than if either of us worked independently. Much of the close coordination between the NAPAP and EPRI programs results also from coordination workshops which we have (along with other groups) sponsored, e.g., the one in Colorado in 1982 and one being planned for this year. I am quite convinced that working together, as we do, the EPRI and NAPAP programs will provide exceedingly valuable scientific information on the issue of acidic deposition.

Let me summarize this testimony by saying that I feel that a fairly strong consensus exists in the scientific community that many significant gaps exist in our understanding of the acidic deposition issue. Whether those gaps are great enough to preclude governmental or industry action is not a question that can be answered scientifically. Because our knowledge will almost always be incomplete, science cannot answer the question, "How much knowledge do we need before we act?" Science can only tell us what is known and perhaps what needs to be known. Fortunately, between private industry and the federal and state governments, a large research effort is underway - one which is continually shedding new light on the issue at hand. Despite that massive research effort, I feel confident in saying that we, the scientists, do not yet have the tools (specifically air-quality models) to judge the efficacy of any control strategy that might be promulgated. As stated in the 1983 Academy report (NAS, 1983, p. 10), "We do not believe it is practical at this time to rely upon currently available models to distinguish among alternative [control] strategies." The regulator or legislator, therefore, faces a difficult question. Does he propose a control strategy that will cost the public money but whose effectiveness cannot be judged in solving a problem which is still not well defined? Society will have to decide the answer to that question. Science cannot.

Mr. Chairman, thank you again for the opportunity to present this testimony.

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April 1984

EPRI

ACIDIC PRECIPITATION RESEARCH AT EPRI

OCTOBER 1983

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ACIDIC PRECIPITATION RESEARCH

October 1983

INTRODUCTION

Acidic precipitation is a major environmental concern to society in general and to the utility industry in particular. The concern centers around three claims: (1) precipitation, at least in the eastern United States, is becoming more acidic and the area being affected is getting larger, (2) acidic deposition is causing severe ecological damage, and (3) coal burning by utility companies is a major contributor to the occurrence of such precipitation. It is the third claim which causes concern to the utility industry and which is the stimulus for EPRI's extensive research effort on the subject. In addition, various regulatory and legislative acts are being considered--acts which seek, through control of emissions, to minimize any damage that might result from acidic precipitation. A comprehensive research program by EPRI, therefore, may be able to provide sound scientific data that can be of use to regulators or legislators. Two factors, therefore, play a role in EPRI's decision to undertake acidic precipitation research: (1) concern over the fact that coal burning may be a major contributor to acidic precipitation, and (2) the desire to provide sound scientific data in view of pending regulations.

Admittedly, coal burning does emit sulfur oxides and nitrogen oxides which can be the precursors for the sulfuric and nitric acids in precipitation; however, the utility contribution to the acidity is highly uncertain, hence the efficacy of an emission reduction in reducing rain acidity is fraught with uncertainty. We cannot judge how effective a control strategy will be in reducing the acidity of precipitation and, therefore, in reducing any ecosystem damage that might be attributed to the precipitation.

ACIDIC PRECIPITATION RESEARCH AT EPRI

EPRI's acidic precipitation research is carried out principally in the Environmental Assessment Department of the Energy Analysis and Environment Division. The research will produce scientific data which will be available to the public. EPRI will not use the results to recommend any policy or regulatory action, although we hope that other industry groups and the government will make use of our scientific data in its policy actions.

In August 1978, the Environmental Assessment Department sponsored a workshop to identify the research needed to understand better the formation of acidic precipitation (WS-78-98, EPRI Report EA-1074). Participants included people from the utility industry, government, and academia. A similar workshop was conducted to discuss the effects of acidic deposition on ecosystems (SOA77-403, EPRI Report EA-79-6-LD). These workshops had two main purposes: (1) to identify specific problems related to acidic precipitation, and (2) to identify areas of needed research. With the help of such planning workshops, the EPRI acidic precipitation research plan has developed.

The major objective of the EPRI acidic precipitation research is to identify the utility contribution to acidic precipitation effects. The enormity of this task requires that we divide it into several subobjectives, the first two being (1) utility contribution to ecosystem damage, and (2) utility contribution to materials damage (Figure 1). Because the public and industry are primarily concerned with ecosystem damage, the Environmental Assessment Department has focused its attention on this aspect of the acid rain problem. The subject of utility contribution to ecosystem damage is further divided into two distinct objectives (Figure 1) and these are being studied as separate questions. This allowed for both a clear division of tasks among departmental programs and greater simplicity in dealing with a multi-faceted problem.

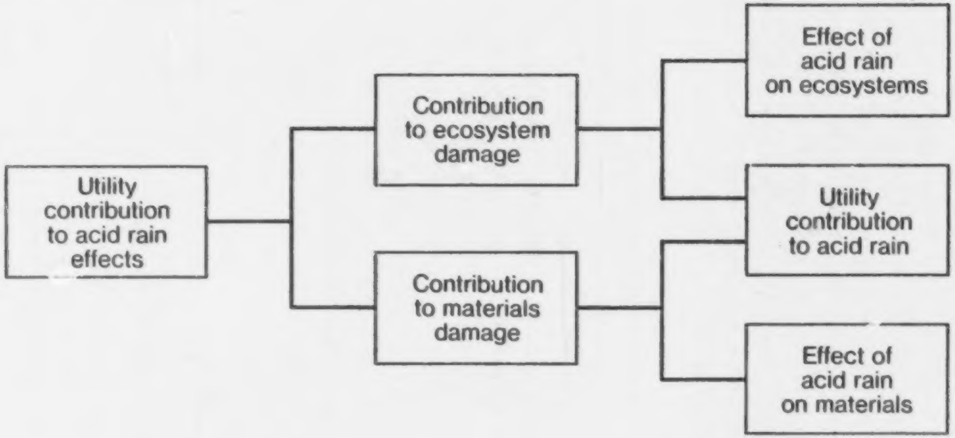

Utility contribution to acid rain effects
Contribution to ecosystem damage
Contribution to materials damage
Effect of acid rain on ecosystems
Utility contribution to acid rain
Effect of acid rain on materials

Figure 1

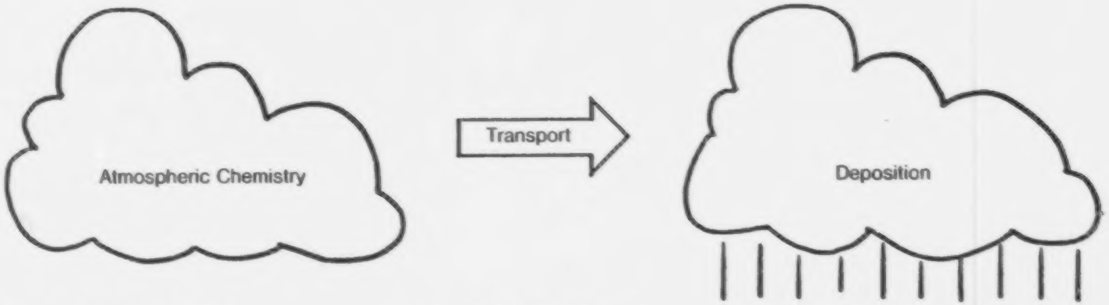
EPRI Acidic Precipitation Research Activities

The Environmental Physics and Chemistry Program is addressing the question of utility contribution to acidic precipitation. Understanding how acids are incorporated into clouds, how they are transported from the source and what chemical processes occur during transport is crucial to meeting their objective (Figure 2a).

Determining the effect of acidic deposition on ecosystems is handled by the Ecological Studies Program. The response to increased acidity by soil, water, flora, fauna, and the integrated ecological systems that these form is to be identified by this program (Figure 2b).

Precipitation research conducted by these two programs interfaces in the area of deposition. As wet and dry deposition is governed by both atmospheric and ecological factors, the responsibility for studying it is shared by both programs.

In addition to research being conducted by the Environmental Assessment Department, the Economic and Environmental Integration Group (Divisional Director's staff) is carrying out three projects dealing with acidic precipitation (Figure 2c). One is a study of materials damage from acid precipitation. A second is a study of the economic impact of acidic precipitation on crops. The third is a decision analysis project which aims to develop a framework (or methodology) by which the implications (cost/benefit) of different policy options could be assessed in the light of the many uncertainties associated with the acid deposition issue. It should be apparent that these three projects depend heavily on findings coming from the research in the Environmental Assessment Department. Similarly, the work in the Environmental Assessment Department depends on findings from the Economic and Environmental Integration Group. For example, we cannot evaluate the utility contribution to acidic precipitation damage unless we factor in the effects of the precipitation on materials. The work of the two groups



- North Sea study (CERL)
- Regional air quality studies
- Cloud model application to identify important chemical mechanisms
- Effects of aerosols and cloud droplets on transformation of SO_x
- Cloud water acidity and formation mechanisms
- Lab chemistry/kinetics (planned)
- Precipitation studies in western U.S. (planned)

$ Millions	
Through 1983	*1984—1988*
4.0	10.0

- North Sea study (CERL)
- Regional air quality studies
- Long range tracer studies

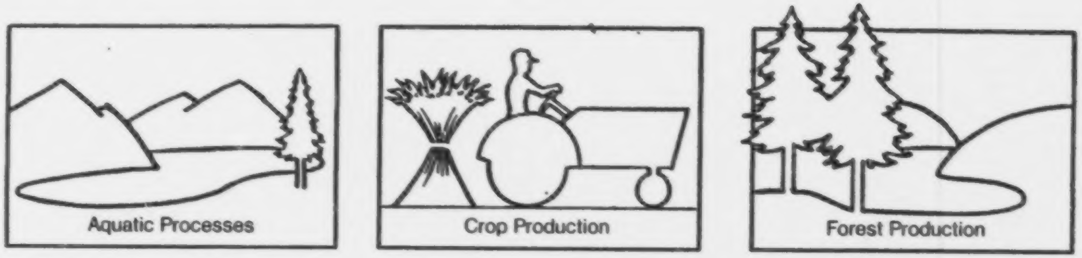
$ Millions	
Through 1983	*1984—1988*
3.8	22.7

- Characterizing acid precipitation in the Adirondacks
- Modeling dry deposition of SO_2 and sulfate aerosols
- Precipitation monitoring in eastern U.S.
- UAPSP ($ not included)
- Dry deposition studies
- Receptor modeling
- Precipitation studies in western U.S. (planned)

$ Millions	
Through 1983	*1984—1988*
3.1	7.8

Figure 2a

EPRI ACIDIC DEPOSITION RESEARCH



Aquatic Processes

- Integrated lake watershed acidification study
- Effects on aquatic processes
- Regional integrated lake watershed acidification study
- Mitigation studies (liming)
- Fisheries and lake acidification

$ Millions	
Through 1983	*1984—1988*
8.0	16.2

Crop Production

- Response of agricultural soils to acid precipitation
- Effects on agricultural crops

$ Millions	
Through 1983	*1984—1988*
2.8	3.9

Forest Production

- Microcosm evaluation of effects
- Effects on nutrient status of forest ecosystem
- Forest canopy interactions
- Aluminum mobilization
- Ground water effects (planned)
- Mitigation studies (planned)

$ Millions	
Through 1983	*1984—1988*
2.6	10.9

Figure 2b

EPRI ACIDIC DEPOSITION RESEARCH

$

Economic Evaluations

- Materials damage
- Crop damage

$ Millions	
Through 1983	*1984—1988*
0.6	1.0

?

Decision Tools

- Decision framework for evaluating control measures

$ Millions	
Through 1983	*1984—1988*
0.3	1.0

Figure 2c

EPRI ACIDIC DEPOSITION RESEARCH

(Environmental Assessment Department and Economic and Environmental Integration Group) is closely coordinated. Members from each group serve in an advisory capacity for each other in planning sessions.

Within EPRI, no other direct acidic precipitation research is being conducted. A considerable amount of research, however, on emissions control is carried out by the Coal Combustion Systems Division. This control research, however, is not specifically directed at the problem of acidic precipitation; nevertheless, the control and environmental groups exchange information on a regular basis and coordinate their efforts in public presentations.

EPRI is closely coordinating its efforts with both the utility industry and the federal government. In 1981 the utility industry established an eastern and central U.S. monitoring program, the Utility Acid Precipitation Study Program (UAPSP). The Environmental Assessment Department was responsible for the original network design and is now managing the project even though funding comes entirely from the industry and not from the EPRI budget. The principal federal government effort is channeled through the Interagency Task Force on Acid Precipitation. Members of the Environmental Assessment Department have been involved in the review of the federal research plan. In addition, on a program level, we have coordinated our research with the ecological studies being conducted by EPA and with the atmospheric chemistry research carried out by the Department of Energy. Specific coordination will be noted in following project descriptions.

ENVIRONMENTAL PHYSICS AND CHEMISTRY PROGRAM

The objectives of the EP&C Program in the area of acidic precipitation are (1) to establish the relationships between the chemical composition of precipitation and emissions in the atmosphere, and (2) to develop the ability to identify the relative contribution of fossil-fueled power plants to atmospheric deposition. The work can be further described from a systems approach, with studies divided into five components: emission sources, physical and chemical transformation, dilution and transport, in-cloud chemistry, and deposition (Figure 3). Work is in progress in all of these areas.

Emission Sources

Emissions research aims to characterize the spacial and temporal variability of emissions from various sources. This is being done through emission inventories and source measurements. Interpretive data analysis of air quality measurements (receptor modeling) will also be used.

Chemical Transformations

The goal in this study area is to understand the physical and chemical reactions which contribute to acidic precipitation from source to deposition. Field measurements, laboratory experiments and models are used.

Long Range Transport

These studies are attempting to understand and predict the dilution and transport of pollutants emitted by both large single and multiple sources over regional areas. Simulation modeling, field measurements, and theoretical development are the techniques being applied.

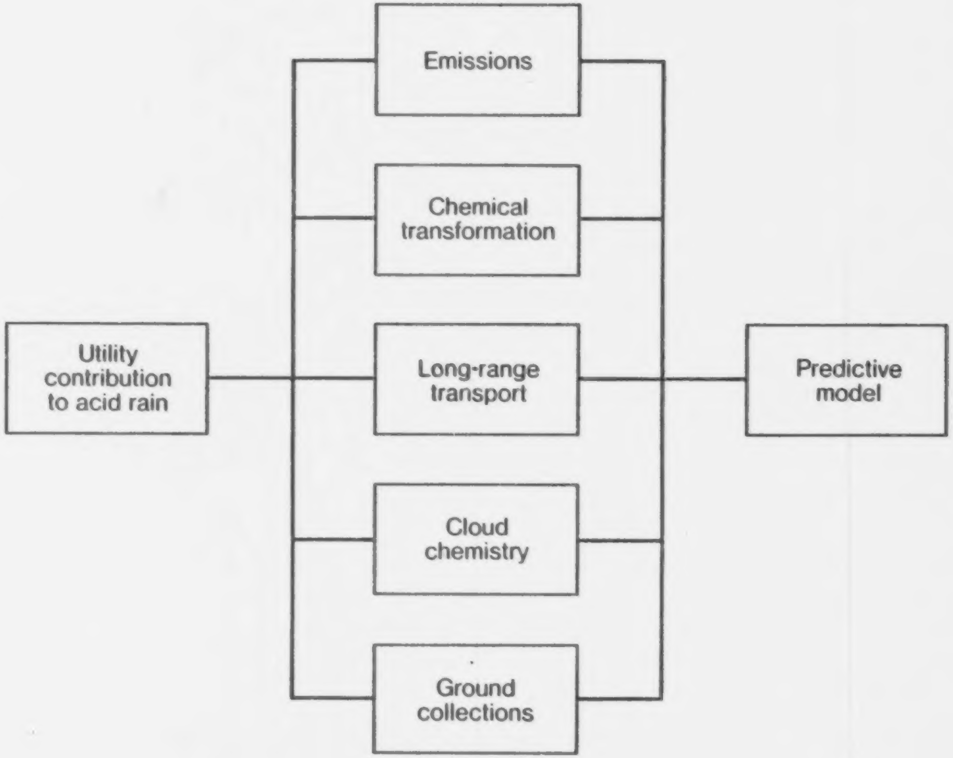

Utility
contribution
to acid rain
Emissions
Chemical
transformation
Long-range
transport
Cloud
chemistry
Ground
collections
Predictive
model

Figure 3

Acidic Precipitation Research
Environmental Physics and Chemistry Program

Cloud Chemistry

The emphasis here is to identify the specific in-cloud mechanisms by which cloud water becomes acidic. Studies focus on actual in-cloud measurements and on laboratory experiments.

Ground Collections

The objective of identifying the mechanisms involved in wet and dry depositional processes is shared by the Environmental Physics and Chemistry Program and the Ecological Studies Program. Methods used are field measurements, laboratory studies, and mathematical modeling. Because there is no accurate way to measure directly dry deposition, theoretical and experimental approaches are being taken.

The completed and active acidic precipitation-related projects, conducted by the Environmental Physics and Chemistry Program, are listed in Table 1. Following Table 1 are 1-page descriptions of each project (arranged in numerical order by project number). Additional information on the interrelation of these projects and of future planned research costs is covered in the Appendix.

Table 1

ENVIRONMENTAL PHYSICS AND CHEMISTRY PROGRAM
Acidic Precipitation Research (current and complete)

Project Number	Title	Present Project Term
EMISSIONS		
RP862	Sulfate Regional Experiment	1976-1981
RP1630-23	Source Emissions Inventory for the E&WRAQS	1982-1984
CHEMICAL TRANSFORMATION		
RP1434	The Effects of Aerosols and Cloud Droplets on the Nighttime Transformation of Sulfur Oxides	1978-1983
RP1630-12	Development of a Method to Measure for H_2O_2 in Air, Cloudwater, and Rainwater	1981-1984
RP2022	Cloud Model Application to Identify Important Chemical Mechanisms	1981-1982
RP2375	Method for Measuring Atmospheric Hydrogen Peroxide	1983-1984
LONG-RANGE TRANSPORT		
RP862	Sulfate Regional Experiment	1976-1981
RP1311	Atmospheric Chemistry Related to the Formation of Acid Precipitation (North Sea Study)	1978-1981
RP1630	Regional Air Quality Studies	1979-1986
RP2370	Long-Range Tracer Experiment-CAPTEX	1983-1984
RP2434	Massive Aerometric Tracer Experiment (MATEX) - Planning Phase	1983-1984

CLOUD CHEMISTRY		
RP1311	Atmospheric Chemistry Related to the Formation of Acid Precipitation (North Sea Study)	1978-1981
RP2023	Cloud Water Acidity Measurements and Formation Mechanisms	1981-1985
GROUND COLLECTIONS		
RP1155	Characterization of Acid Precipitation in the Adirondack Region	1977-1979
RP1306	Modeling of Dry Deposition of SO_2 and Sulfate Aerosols	1978-1980
RP1376, RP1630-2	Monitoring of Precipitation Chemistry in the Eastern United States	1976-1982
RP1630-26	Dry Deposition Intercomparison Study	1982
RP2199	Receptor Modeling-Source Apportionment	1983-1984
RP2264	Atmospheric Deposition of Sulfate During the SURE	1982-1985

Advisory Workshop to Identify Research Needs on the Formation of Acid Precipitation - WS78-98

OBJECTIVES

- Examine the state of the scientific knowledge with special emphasis on uncertainties.
- Distill and present a high priority set of research needs.
- Publish and disseminate this material as a contribution to the requirements for understanding acid precipitation.

APPROACH

- Workshop.

CONTRACTOR

- Sigma Research, Inc.

STATUS

- Complete.

PROJECT TERM

- 1978.

RESULTS

- Research recommendations developed.
- Workshop proceedings published, EPRI Report EA-1074.

PRODUCTS

- Report.

Sulfate Regional Experiment - RP862 (SURE)

OBJECTIVES

- To develop a means of predicting ambient concentrations of a secondary pollutant (e.g., sulfate) in terms of the emission of its precursor (e.g., SO_2) from the power plant source. In order to meet the objective of SURE, an accurate emissions inventory had to be developed.

APPROACH

- Develop the inventory by updating NEDS data and by direct contact with utility companies in order to develop daily emissions data. Air Quality data was gathered through a network of 54 stations throughout the eastern U.S.

CONTRACTORS

- Environmental Research and Technology, Inc., Meteorology Research, Inc., Research Triangle Institute, GCA, SRI International, AeroVironment Inc.

STATUS

- Complete; Approximately 37 report volumes are being published.

PROJECT TERM

- 1976 - 1981.

RESULTS

- Regional ambient sulfate concentrations are typically low, less than 10 $\mu g/m^3$ 75% of the time.
- High sulfate values (up to 40-50 $\mu g/m^3$) do occur, but do not correlate simply with changes in emissions.
- Certain sulfate episodes correlate with specific meteorological conditions, e.g., temperature and dew point temperature.
- Whereas SO_2 emissions may vary by 10-15% day-by-day, SO_4 concentrations may vary by hundreds of percent.
- On an annual basis, the electric utilities emitted approximately 56% of the SO_2 and 30% of the NO emissions in the SURE region in 1977.
- A mathematical model was developed for estimating biogenic sulfur emissions in the SURE region (RP856). The model showed that at least 53,500 metric tons of biogenic sulfur are emitted from the SURE land surfaces (~1 to 2% of the anthropogenic sulfur contribution).

PRODUCTS

- Reports; SURE summary presentations; Extensive data sets; foundation for continuation of research under RAQS (RP1630).

Characterization of Acid Precipitation in the Adirondack Region - RP1155

OBJECTIVE

- To measure the acidity and selected chemical species in rain and snow in three watersheds in the Adirondack region.
- To test the hypothesis that the three watersheds receive similar inputs.

APPROACH

- Daily sampling of precipitation, followed by chemical analysis.

CONTRACTOR

- Rensselaer Polytechnic Institute.

STATUS

- Completed; Report published; Continued work under RP1109.

PROJECT TERM

- 1977 - 1980.

RESULTS

- Despite the different acidities of the lakes in the three watersheds, the precipitation quality being received at each is nearly identical on a monthly and annual basis.
- Investigations of temporal variations of different chemical species indicated some winter-to-summer and summer-to-summer differences.

PRODUCTS

- Data set; Report.

COMMENT:

- This work done in close cooperation with the Ecological Studies Program, especially with the Adirondack Lake Study (ILWAS-RP1109).

Modeling of Dry Deposition of SO_2 and Sulfate Aerosols - RP1306

OBJECTIVE

- Provide a comprehensive understanding of the rates at which airborne pollutants are deposited on the earth's surface.
- Translate the understanding into mathematical forms which can be incorporated into regional air quality models.
- Evaluate experimental measurements required to predict deposition losses correctly.

APPROACH

- Literature review.
- Theoretical evaluation.
- Mathematical modeling.

CONTRACTOR

- Aeronautical Research Associates.

STATUS

- Successfully completed; Final report published.

PROJECT TERM

- 1978 - 1980.

RESULTS

- A general, parameterized model for dry deposition has been developed.
- The model has been validated for the case of a cornfield canopy.
- The existing experimental data do not, for the most part, contain appropriate information necessary to predict dry deposition with the accuracy this work has shown is possible.

PRODUCTS

- Final report.

Atmospheric Chemistry Related to the Formation of Acid Precipitation - RP1311

OBJECTIVES

- Define the role that power plant emissions (especially SO_2) play in the formation of acidic droplets in clouds.
- Predict the effect that reducing SO_2 emissions will have on the acidity of precipitation that falls at distances of hundreds of kilometers from the SO_2 source (North Sea precipitation project).

APPROACH

- Instrumentation development.
- Aircraft measurements in clouds over the North Sea coupled with tracer injection.

CONTRACTOR

- Central Electricity Research Laboratory (United Kingdom).

STATUS

- Complete; Reports published by CERL.

PROJECT TERM

- 1978 - 1981.

RESULTS

- Successful development, installation and testing of a cloud water separator/collector, and tracer detector for aircraft use.
- Cloud droplets were observed to have very low pH values, on occasion approaching pH = 2.0.
- Individual power plant plumes observed at distances up to 700 km.

PRODUCTS

- Final reports.

COMMENTS

- Funding for this research was supplied by both EPRI and the Central Electricity Generating Board (U.K.).

Monitoring Precipitation Chemistry in the Eastern United States - RP1376

OBJECTIVE

- Monitor the amount and chemical nature of precipitation falling within the SURE study region. (eastern U.S.A.).
- Correlate the rain chemistry with other air quality parameters.

APPROACH

- Ground monitoring.
- Laboratory analysis.
- Modeling.

CONTRACTOR

- Rockwell International Air Monitoring Center.

STATUS

- Work started under this project is being completed under RP1630.

PROJECT TERM

- 1978 -1981.

RESULTS

- Over the 22-month period of data collection, rain acidity typically fell in the low 4 pH range.
- Annual averages suggest a slight rise in pH during the 22-month time period.
- A drop of 0.2 to 0.3 pH units in midsummer was identified as a seasonal trend.
- A slight geographic difference was also detected, with the lowest pH values occurring in the northeast and the highest in the south. No prominent east-west trend was observed.

PRODUCTS

- No final report published; Work continued under RP1630.

The Effects of Aerosols and Cloud Droplets on the Nighttime Transformation of Sulfur Oxides - RP1434

OBJECTIVE

- Determine the conversion of SO_2 to SO_4 under various pollutant concentrations, temperatures, humidity, and cloud liquid water content conditions which can occur at night.
- Measure the modification of particles, especially the changes in their chemical composition, physical size, and properties for absorbing water and light caused by in-plume processes.
- Test theoretical kinetic models for predicting conversion rates.

APPROACH

- Laboratory experiments using a reactive/dynamic cloud chamber.
- Instrument development.
- Data analysis.

CONTRACTOR

- Desert Research Institute.

STATUS

- In progress.

PROJECT TERM

- 1977 - 1983.

RESULTS

- A laboratory capability for studying the transfer of SO_2 and NO_2 to cloud water drops was developed.
- SO_2 oxidation to sulfate in cloud water droplets increases the size of the original cloud condensation nuclei (CCN enhancement).
- The conversion of SO_2 in cloud water droplets leads to particles which condense water more efficiently, i.e., the potential for cloud and fog formation is enhanced.
- CCN enhancement by SO_2 may lead to selective removal of atmospheric sulfates by precipitation.

- The conversion of SO_2 to sulfate in clouds is not significantly influenced by the chemical composition, particle size or number of CCN.
- In the absence of O_3, H_2O_2 and NO_2 the rate of conversion of SO_2 is less than 1%/hr.
- The rate of conversion of SO_2 in the presence of CCN, NH_3, O_3 and H_2O_2 is in the range of 10 to 30%/hr.
- The rate of conversion of SO_2 in the presence of CCN, NH_3, and NO_2 may be as great as 100%/hr.
- Experiments are to be repeated with no NH_3 in the starting mixtures.

PRODUCTS

- Reports.

COMMENTS

- Work coordinated with the Coordinating Research Council.

Precipitation Chemistry Measurements in the Northeastern United States - RP1630-2 (RAQS)

OBJECTIVE

- To measure the spatial and temporal variations of precipitation chemistry in the northeastern U.S.

APPROACH

- Field measurements (nine sites, duplicate collectors).
- Statistical analysis.

CONTRACTOR

- Rockwell International.

STATUS

- Technically complete.

PROJECT TERM

- 1979 - 1982.

RESULTS

- A precipitation monitoring study was performed from August-September 1978 through June 1980 with a network of nine stations in the SURE region; the program continued through December 1980 with seven of the sites and through December 1981 with 5 sites.
- Annual average pH at these sites was approximately 4.2.
- Spatially, the precipitation results showed an increase in acid concentration from south to north and also from west to east.
- Sulfate and nitrate generally correlated with H^+.
- Much higher values occurred in the warm months for H^+, conductivity, NH_4^+, Ca^{+2}, $SO_4^=/NO_3^-$ and total ion equivalents. Na^+ and Cl^- were higher during winter months.
- Convective storms were found to contain the highest concentrations of H^+, $SO_4^=$, and NO_3^-, and the largest volume of precipitation; the lowest concentration of acidity constituents were associated with cyclonic events, especially hurricanes.

PRODUCTS

- Report; Data set on magnetic tape.

COMMENTS

- This contract was co-funded by ECAR and EEI (~20%). The network design has been used and the network expanded by the Utility Acid Precipitation Study Program (UAPSP). UAPSP is currently funding a 20-station network in the southern, midwestern, and eastern U.S. EPRI serves as the UAPSP project manager.

Development of a Method to Measure for Hydrogen Peroxide in Air, Cloud Water, and Rainwater - RP1630-12

OBJECTIVE

- Develop a new method for the measurement of hydrogen peroxide (H_2O_2) from aircraft. This method would be applicable to air, cloud water, and rainwater samples.

APPROACH

- Experimental methods development.
- Field testing.

CONTRACTOR

- National Center for Atmospheric Research.

STATUS

- In progress.

PROJECT TERM

- 1981 - 1984.

RESULTS

- An automated analytical technique for the determination of hydrogen peroxide in the liquid phase has been developed. The chemistry of this technique is based on the reaction of H_2O_2 with horseradish peroxidase and parahydroxyphenyl-acetic acid.
- Techniques have been developed for collection, handling and analysis of aqueous H_2O_2 samples.

PRODUCTS

- Report; New methods development.

Regional Air Quality Model Assessment and Evaluation - Phase I - RP1630-21

OBJECTIVE

- Assess the accuracy and precision of existing, state-of-the-art regional air quality models when they are used to predict the transport, chemistry, and deposition of pollutants from multiple sources.

- Identify major areas of strengths and weakness in existing regional air quality model formulations, including physical rationale and simplifying assumptions, input data requirements, and computational techniques.

- Define a research plan that, if successful, will lead to significant improvements in the prediction of selected regional air quality impacts, such as the regional concentrations of the oxides of sulfur and nitrogen, precipitation chemistry, visibility impairment, and trace substances (i.e., trace metals, organic materials, and the like).

APPROACH

- Model evaluation using existing data sets.

CONTRACTOR

- SRI International

STATUS

- In progress.

PROJECT TERM

- 1982 - 1983.

RESULTS (expected)

- Evaluation of existing regional air quality performance.

- Model development research plan (5/84).

PRODUCTS

- Report; Research plan; Computer programs.

Source Emissions Inventory for the
Eastern and Western Regional
Air Quality Studies - RP1630-23

OBJECTIVE

- Prepare basic emissions inventories for SO_x, TEP, NO_x and HC for the conterminous U.S. and parts of Canada. These inventories will be used for interpreting causes of pollutant loading and for development of air quality models.

APPROACH

- Data collection and analysis.
- Data management system development.

CONTRACTOR

- Environmental Research and Technology, Inc.

STATUS

- In progress.

PROJECT TERM

- 1982 - 1984

RESULTS (expected)

- Source categories will include fossil-fueled electric utility plants, other major industries, manufacturing and commercial, home heating, and surface transportation.
- Major point sources will be located exactly; minor point sources and area sources will be allocated to an 80 km grid system.
- Time resolution will be in 3-hour averages by day-of-week and season.

PRODUCTS

- Report; Emissions inventory.

Dry Deposition Intercomparison Study - RP1630-26

OBJECTIVE

- Field test and analyze dry deposition measurement techniques in conjunction with the U.S. EPA dry deposition intercomparison study.

APPROACH

- Field measurements.
- Data analyses.

CONTRACTOR

- Battelle Pacific Northwest Laboratories.

STATUS

- Complete; report published.

PROJECT TERM

- 1982.

RESULTS

- Analysis of the uncertainties inherent in using the gradient transfer approach for determining the deposition velocity of sulfur-containing particles.
- A comparison of the gradient transfer and eddy correlation approaches to deposition of ozone.

PRODUCTS

- Report; Comparisons of dry deposition measurement techniques.

COMMENTS

- Work performed in conjunction with U.S. EPA study.

Precipitation Chemistry Research Priorities - RP1630-35

OBJECTIVE

- Provide a hierarcy of interrelated problems requiring research in precipitation chemistry.
- Identify the information needs in cloud and precipitation chemistry.
- Promote awareness and cooperation within the research community.
- Emphasize the need for standardized methods so that data obtained from separate studies are useful to the modeling community.

APPROACH

- Workshop of prominent research scientists and project managers from the U.S., Canada, W. Germany, Netherlands, and Great Britian.

CONTRACTOR

- State University of New York at Albany.

STATUS

- Completed. Final report being edited.

PROJECT TERM

- 1982.

RESULTS

- High priority ranking suggested for projects related to clouds, dry deposition, and transport.
- High priority suggested for research in SO_x and NO_x chemistry and analyses of existing data sets.
- Improved instrumentation needed for NO_3, HNO_3, NH_3 and H_2O_2.
- Identification of sources and sinks of H_2O_2, studies of reactions of free radicals, studies of the importance of carbonaceous materials inside cloud droplets, and comparisons of reactions in bulk and dispersed phases should receive high priority.

PRODUCTS

- Report.

Cloud Model Application to Identify Important Chemical Mechanisms - RP2022

OBJECTIVE

- Evaluate the wet removal mechanisms in cyclonic storm systems.

APPROACH

- Field study data used to characterize meteorology ahead of rain.
- Mathematical model applied to calculate rain composition.
- Compare calculated vs. actual values.
- Analyze components in model to obtain a perspective on the relative importance of various chemical and physical mechanisms.

CONTRACTOR

- Battelle Pacific Northwest Laboratories.

STATUS

- Work completed; final report in revision.

PROJECT TERM

- 1981 - 1982.

RESULTS

Mathematical simulations performed for a single warm-frontal precipitation event concluded:

- More material was scavenged into the precipitation from the underlying cold air mass than from the overriding warm air mass.
- The direct scavenging of SO_2 and sulfate particles by cloud and raindrops are important processes in delivering rainborne $SO_4^=$ to the surface.
- Reactions involving combined oxidation of SO_2 by H_2O_2 and O_3 in clouds and rain drops create some of the $SO_4^=$ found in the rain.
- Scavenging of PAN did not contribute significantly to nitrate in rain.

PRODUCTS

- Report.

Cloud Water Acidity Measurements and Formation Mechanisms - RP2023

OBJECTIVE

- Evaluate processes by which cloud water attains its acidity.

APPROACH

- Aircraft measurements: Measure concentrations of various chemical species in cloud water, in air around clouds, and in interstitial air between cloud droplets.
- Laboratory studies: Compare experimental data to chemical equilibrium theory; Use experimental data to establish reaction rates.
- Instrumentation development.

CONTRACTOR

- Brookhaven National Laboratory.

STATUS

- In progress.

PROJECT TERM

- 1981 - 1985.

RESULTS

- Technology has been developed or modified and tested for airborne cloud sampling. Sulfur dioxide, ammonia, sulfates between cloud droplets, cloud water conductivity and pH can now be measured in-situ.
- Theoretical analyses, based on the coupling of established physical and chemical principles, indicate that composition of cloud water is governed mostly by chemical reactions in clouds, and is not limited by the rate of materials transfer to cloud droplets.
- Flights have shown that the pH was uniform within nonprecipitating stratiform clouds, but that the concentration of the major chemical species was quite variable.
- Results will determine the relative importance of various mechanisms known to be involved in transferring nitrogen and sulfur oxide emissions to cloud and rainwater. The data will enhance the accuracy of air quality and acidic precipitation models.

PRODUCTS

- Reports; Data.

Receptor Modeling - Source Apportionment - RP2199

OBJECTIVE

- Evaluate in quantitative terms the extent to which receptor modeling is a useful tool for tracing the airborne emissions from coal- and oil-fired power plants.

APPROACH

- Feasibility study.

CONTRACTOR

- SRI International.
- Desert Research Institute.

STATUS

- In progress.

PROJECT TERM

- 1983 - 1984.

RESULTS

- A judgment on the feasibility of receptor modeling for EPRI's objective.
- If found useful, development of a future research plan.

PRODUCTS

- Report.

Atmospheric Deposition of Sulfate During the SURE - RP2264

OBJECTIVE

- Calculate the deposition of sulfates within the SURE area.
- Ascribe observed sulfate deposition patterns to pollutant source areas within the SURE region.

APPROACH

- SURE data analysis.
- ^{210}Pb tracer technique for $SO_4^=$ deposition analysis.

CONTRACTOR

- Yale University.

STATUS

- In progress.

PROJECT TERM

- 1982 - 1985.

RESULTS (expected)

- Proof-of-concept of applying the lead isotope tracer technique to sulfate deposition.
- Estimates of total deposition of sulfate over the SURE area during the SURE, and of selected subperiods and subregions to the extent feasible.

PRODUCTS

- Report.

Long-Range Tracer Experiment - CAPTEX (Cross-Appalachian Tracer Experiment) - RP2370

OBJECTIVE

- Provide preliminary data on the transport and dilution of airborne materials emitted in Ohio as they move across the Appalachian Mts. to the mid-Atlantic and New England areas.
- Provide design criteria and data for a massive tracer/chemistry experiment anticipated after 1984.
- Provide tracer material for use in CAPTEX.

APPROACH

- Field experiments and monitoring (use of tracer).
- Laboratory studies and data analysis.

CONTRACTOR

- ISC Chemicals Limited (tracer).
- Battelle Pacific NW Laboratories.

STATUS

- In progress.

PROJECT TERM

- 1983 - 1984.

RESULTS (expected)

- A meteorological data set on upper air and surface winds and temperature that may be used to determine the sensitivity of trajectory calculations to the frequency and density of upper air measurements.
- Analysis and recommendations on the upper air network required for a massive tracer/chemistry experiment.

PRODUCTS

- Report; Data sets.

COMMENTS

- EPRI activity in CAPTEX is supplemental to DOE, NOAA, EPA and AES.

TABLE 10

REGIONAL COAL PRODUCTION: AHR CASE[a]
(million tons)

Region	1980	Forecast 1985	Forecast 1990	Forecast 1995	Change from 1980 1985	Change from 1980 1990	Change from 1980 1995
Northern Appalachia	185	175	170	181	-10	-15	-4
Central Appalachia	233	272	320	338	39	87	105
Southern Appalachia	26	32	29	26	6	3	-
Total, Appalachia[b]	444	478	520	545	34	76	101
Midwest	134	108	103	101	-26	-31	-33
Eastern Northern Great Plains	17	23	32	32	6	15	15
Western Northern Great Plains	125	169	219	260	44	94	135
Total, Northern Great Plains[b]	142	193	251	292	51	109	150
Central West	13	14	18	23	1	5	10
Gulf	29	39	87	126	10	58	97
Rockies	32	47	74	111	15	42	79
Southwest	29	38	58	81	9	29	52
Northwest	5	5	5	6	-	-	1
Alaska	1	4	10	12	3	9	11
Total, Rest of West[b]	109	147	252	360	38	143	251
Total, United States[b]	830	925	1,125	1,298	95	295	468

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[a] Regional details in Attachment A-1.

[b] Totals may not add due to independent rounding.

TABLE 11

REGIONAL COAL PRODUCTION: BASE CASE[a]
(million tons)

Region	1980	Forecast 1985	Forecast 1990	Forecast 1995	Change from 1980 1985	Change from 1980 1990	Change from 1980 1995
Northern Appalachia	185	183	195	213	-2	10	28
Central Appalachia	233	253	276	295	20	43	62
Southern Appalachia	26	32	29	26	6	3	-
Total, Appalachia[b]	444	467	500	534	23	56	90
Midwest	134	130	158	182	-4	24	48
Eastern Northern Great Plains	17	23	32	33	6	15	16
Western Northern Great Plains	125	168	211	250	43	86	125
Total, Northern Great Plains[b]	142	191	243	283	49	101	141
Central West	13	15	24	23	2	11	10
Gulf	29	39	87	126	10	58	97
Rockies	32	40	54	73	8	22	41
Southwest	29	37	48	61	8	19	32
Northwest	5	5	5	6	-	-	1
Alaska	1	4	10	12	3	9	11
Total, Rest of West[b]	109	139	227	302	30	118	193
Total, United States[b]	830	927	1,127	1,300	97	297	470

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a/ Regional details in Attachment A-2.

b/ Totals may not add due to independent rounding.

TABLE 12

REGIONAL COAL PRODUCTION BY SULFUR CONTENT
(mmtons/year)

		1985		1990		1995	
	1980	ANR Case	Changes from Base	ANR Case	Changes from Base	ANR Case	Changes from Base
Northern Appalachia							
Metallurgical	34.1	29.3	+1.3	33.4	+1.5	34.1	+0.5
Low Sulfur	0.3	0.7	+0.7	0.4	+0.1	0.1	+0.1
Medium Sulfur	54.9	76.8	-1.0	74.5	-11.1	84.2	-15.3
High Sulfur	95.8	68.4	-8.6	62.0	-15.4	62.5	-17.4
Total	185.1	175.2	-7.6	170.4	-24.9	180.9	-32.1
Central Appalachia							
Metallurgical	76.6	73.9	-1.6	74.7	-1.5	76.7	-0.4
Low Sulfur	16.1	40.7	+1.5	101.2	+36.7	128.1	+42.5
Medium Sulfur	131.9	154.5	+18.7	142.2	+9.4	132.1	+1.4
High Sulfur	8.2	2.4	-	1.7	-0.3	1.2	-0.1
Total	232.8	271.5	+18.6	319.9	+44.3	338.1	+43.4
Southern Appalachia							
Metallurgical	9.8	9.9	-	9.6	-0.3	9.3	-
Low Sulfur	1.1	3.0	-1.7	4.2	-1.6	4.6	-0.2
Medium Sulfur	15.5	18.8	+1.9	15.6	+2.8	11.5	-0.2
High Sulfur	-	-	-	-	-	-	-
Total	26.4	31.7	+0.2	29.4	+0.9	25.5	-0.4
Midwest							
Metallurgical	2.9	3.0	+0.3	2.2	-	1.3	-
Low Sulfur	0.1	-	-	-	-	-	-
Medium Sulfur	16.2	21.8	+2.1	26.5	+0.7	25.3	-1.1
High Sulfur	115.1	82.7	-24.6	74.1	-55.7	74.1	-80.1
Total	134.4	107.5	-22.2	102.8	-55.0	100.8	-81.2
Eastern Northern Great Plains							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	-	-	-	-	-	-	-
Medium Sulfur	17.3	23.3	-	31.7	-	32.1	-0.9
High Sulfur	-	-	-	-	-	-	-
Total	17.3	23.3	-	31.7	-	32.1	-0.9
Western Northern Great Plains							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	67.6	117.5	+3.6	151.1	+7.4	176.3	+9.8
Medium Sulfur	56.9	51.8	-1.8	67.8	+0.7	83.9	+0.8
High Sulfur	-	-	-	-	-	-	-
Total	124.5	169.3	+1.8	218.9	+8.1	260.3	+10.6

TABLE 12 (Continued)

REGIONAL COAL PRODUCTION BY SULFUR CONTENT
(mmtons/year)

		1985		1990		1995	
	1980	ANR Case	Changes from Base	ANR Case	Changes from Base	ANR Case	Changes from Base
Central West							
Metallurgical	0.7	0.8	+0.1	0.8	+0.1	0.9	-
Low Sulfur	0.2	0.9	+0.1	2.4	+0.6	2.3	-0.1
Medium Sulfur	0.7	2.0	+0.1	5.4	-0.4	8.1	+1.4
High Sulfur	11.0	10.4	-1.0	9.1	-6.2	11.9	-1.3
Total	12.6	14.1	-0.7	17.7	-5.9	23.2	-
Gulf							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	-	-	-	-	-	-	-
Medium Sulfur	29.4	38.6	-	86.6	-	121.1	-
High Sulfur	-	-	-	-	-	5.1	-
Total	29.4	38.6	-	86.6	-	126.2	-
Rocky Mountains							
Metallurgical	3.2	2.5	-0.1	2.7	+0.1	2.7	-0.1
Low Sulfur	[illegible].6	36.2	+3.5	58.3	+14.9	90.3	+34.8
Medium Sulfur	4.3	7.8	+2.6	13.2	+4.9	18.1	+3.9
High Sulfur	-	-	-	-	-	-	-
Total	32.1	46.6	+6.0	74.3	+19.9	111.2	+38.6
Southwest							
Metallurgical	0.8	-	-	-	-	-	-
Low Sulfur	16.0	19.6	+1.3	31.6	+9.4	44.9	+13.4
Medium Sulfur	12.5	16.8	+0.4	26.7	+1.3	36.2	+6.4
High Sulfur	-	-	-	-	-	-	-
Total	29.3	36.4	+1.7	58.2	+10.7	81.1	+19.8
Northwest							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	-	-	-	-	-	-	-
Medium Sulfur	5.1	5.0	+0.3	5.1	-	6.3	-
High Sulfur	-	-	-	-	-	-	-
Total	5.1	5.0	+0.3	5.1	-	6.3	-
Alaska							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	0.8	3.9	-	10.1	-	12.3	-
Medium Sulfur	-	-	-	-	-	-	-
High Sulfur	-	-	-	-	-	-	-
Total	0.8	3.9	-	10.1	-	12.3	-
Total U.S.							
Metallurgical	127.8	119.5	-	123.5	-0.1	125.1	-
Low Sulfur	126.2	222.5	+9.0	359.4	+67.5	459.0	+100.3
Medium Sulfur	341.6	419.2	+23.3	495.3	+8.3	559.0	-3.6
High Sulfur	234.1	163.9	-34.[illegible]	146.9	-77.6	154.9	-98.9
Total	829.7	925.1	-1.9	1,125.1	-1.9	1,298.0	-2.2

TABLE 13

SHIFTS IN COAL MINING AND TRANSPORTATION EMPLOYMENT: ANR CASE

	Average Number of Workers in 1980 (10^3 workers)	Change in Employment from 1980 (10^3 workers)		
		1985 ANR Case	1990 ANR Case	1995 ANR Case
A. COAL MINING[a]				
Northern Appalachia	69	-1	+2	+10
Central Appalachia	93	+22	+49	+62
Southern Appalachia	11	+3	+3	+3
Total, Appalachia[c]	173	+25	+53	+75
Midwest	35	-6	-6	-6
Eastern Northern Great Plains	2	+1	+1	+1
Western Northern Great Plains	6	+2	+6	+8
Total, Northern Great Plains[c]	8	+3	+7	+10
Central West	3	+1	+3	+5
Gulf	2	+1	+5	+10
Rockies	7	+5	+10	+18
Southwest	2	+1	+5	+9
Northwest	1	-	-	-
Alaska	-	-	+1	+1
Total, Rest of West[c]	15	+7	+24	+43
Total U.S.[c]	231	+28	+77	+121
B. COAL TRANSPORTATION[b]				
Transportation Employment	15	+3	+7	+13
C. TOTAL, MINING AND TRANSPORTATION				
Coal Mining	231	+28	+77	+121
Transportation	15	+3	+7	+13
Total[c]	246	+31	+84	+134

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[a] Details in Attachment A-1.

[b] Details in Attachment A-3.

[c] Totals may not add due to independent rounding.

TABLE 14

SHIFTS IN COAL MINING AND TRANSPORTATION EMPLOYMENT: EPA BASE CASE

	Average Number of Workers in 1980 (10³ workers)	Change in Employment from 1980 (10³ workers)		
		1985 Base Case	1990 Base Case	1995 Base Case
A. COAL MINING[a]				
Northern Appalachia	69	+2	+11	+25
Central Appalachia	93	+15	+28	+41
Southern Appalachia	11	+3	+3	+3
Total, Appalachia[c]	173	+20	+42	+69
Midwest	35	-1	+8	+17
Eastern Northern Great Plains	2	+1	+1	+1
Western Northern Great Plains	6	+2	+4	+7
Total, Northern Great Plains[c]	8	+3	+5	+8
Central West	3	+1	+4	+5
Gulf	2	+1	+5	+10
Rockies	7	+3	+6	+10
Southwest	2	-	+2	+4
Northwest	1	-	-	-0
Alaska	-	-	+1	+1
Total, Rest of West[c]	15	+5	+18	+30
Total U.S.[c]	231	+27	+74	+124
B. COAL TRANSPORTATION[b]				
Transportation Employment	15	+3	+7	+11
C. TOTAL, MINING AND TRANSPORTATION				
Coal Mining	231	+27	+74	+124
Transportation	14	+3	+7	+11
Total	246	+30	+81	+135

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[a] Details in Attachment A-2.

[b] Details in Attachment A-4.

[c] Totals may not add due to independent rounding.

ESTIMATED COAL PRODUCTION AND COAL MINING EMPLOYMENT: AMR CASE

Supply Region		Production (10^6 tons)				Average Number of Workers (10^3 workers)				Employment Change from 1980 (10^3 workers)		
		1980	1985 AMR Case	1990 AMR Case	1995 AMR Case	1980	1985 AMR Case	1990 AMR Case	1995 AMR Case	1985 AMR Case	1990 AMR Case	1995 AMR Case
Northern Appalachia												
	PC	61.4	63.1	56.0	51.0	22.1	24.1	23.4	23.0	+2.0	+1.3	+0.9
	PW	31.7	35.5	40.3	46.3	13.9	16.8	19.7	22.7	+2.9	+5.8	+8.8
	OH	39.4	30.3	24.5	33.7	14.7	11.3	9.1	13.2	-3.4	-5.6	-1.5
	MD	3.0	4.0	3.2	2.9	1.1	1.1	1.0	1.2	+0.1	-0.1	+0.1
	NW	40.0	42.4	46.4	47.0	17.3	15.1	17.3	19.5	-2.2	-	+2.2
Total		175.5	175.2	170.4	180.9	69.1	68.5	70.6	79.4	-0.6	+1.5	+10.3
Central Appalachia												
	WS	72.7	88.4	134.0	160.6	36.9	49.0	69.5	82.3	+12.1	+32.6	+45.4
	VA	41.0	49.4	52.0	45.6	16.1	20.3	22.9	20.9	+4.2	+6.8	+4.8
	EK	109.2	123.1	122.2	121.1	35.7	41.2	44.1	46.5	+5.5	+8.4	+10.8
	TN	9.9	10.6	10.9	10.7	3.9	4.3	4.6	4.6	+0.4	+0.7	+0.7
Total		232.8	271.5	319.8	338.1	92.6	114.9	141.1	154.3	+22.3	+48.5	+61.7
Southern Appalachia												
	AL	26.0	31.7	29.4	25.5	11.4	14.5	14.3	14.1	+3.1	+2.9	+2.7
Total		26.0	31.7	29.4	25.5	11.4	14.5	14.3	14.1	+3.1	+2.9	+2.7
TOTAL APPALACHIA		434.3	478.4	519.7	544.5	173.1	197.8	226.0	247.8	+24.7	+52.9	+74.7
Midwest												
	IL	62.5	43.0	40.6	30.6	17.0	13.8	11.0	8.7	-3.2	-6.0	-8.3
	IN	30.9	25.2	28.1	33.0	5.3	4.4	7.0	9.7	-0.9	+1.7	+4.4
	WK	41.0	39.3	34.2	37.2	12.8	12.5	11.1	10.5	-0.3	-1.7	-2.3
Total		134.4	107.5	102.9	100.8	35.1	30.7	29.1	28.9	-4.4	-6.0	-6.2
TOTAL MIDWEST		134.4	107.5	102.9	100.8	35.1	30.7	29.1	28.9	-4.4	-6.0	-6.2
Eastern Northern Great Plains												
	ND	17.0	23.1	31.5	31.9	1.7	2.3	2.9	2.9	+0.6	+1.2	+1.2
	NS	0.3	0.2	0.2	0.2	-	-	-	-	-	-	-
Total		17.3	23.3	31.7	32.1	1.7	2.3	2.9	2.9	+0.6	+1.2	+1.2
Western Northern Great Plains												
	NW	-	0.0	1.3	1.7	-	0.2	0.3	0.4	+0.2	+0.3	+0.4
	MP	29.6	39.1	49.9	72.0	1.1	1.5	1.8	2.6	+0.4	+0.7	+1.5
	WP	68.9	100.2	122.2	129.2	2.0	2.9	3.6	3.0	+0.9	+1.6	+1.0
	WG	26.1	29.3	45.5	57.3	2.9	3.3	5.7	8.3	+0.4	+2.9	+4.6
Total		124.5	169.3	218.9	260.3	6.0	7.9	11.5	14.3	+1.9	+5.5	+8.3
TOTAL NORTHERN GREAT PLAINS		141.7	192.6	250.6	292.4	7.7	10.2	14.4	17.2	+2.5	+6.7	+9.5

Microcosm Evaluation of Acidic Deposition on Forest Ecosystems - RP1632

OBJECTIVE

- Evaluate response of selected trees to acid precipitatio in terms of productivity and soil fertility.

APPROACH

- Microcosm.
- Simulated precipitation.

CONTRACTOR

- TVA.

STATUS

- Data collection and analysis completed; Final report in preparation.

PROJECT TERM

- 1980 - 1983.

RESULTS

- No significant affects on vegetation observed.
- Cation leaching from the upper soil layers is enhanced by precipitation acidity.
- Measurements taken for the microcosm system agree well with field observations, supporting the thesis that the forest microcosm can be a good surrogate, under appropriate conditions, for the field system.

PRODUCTS

- Report; Methodology development to be used in future studies.

Evaluation of Nitrogen Deposition on Forested Watersheds - RP1727

OBJECTIVE

- Determine effect of acidic deposition on nitrogen cycling in forest ecosystem.

APPROACH

- Experimental watersheds.

CONTRACTOR

- Tennessee Valley Authority.

STATUS

- In progress; Data being collected.

PROJECT TERM

- 1980 - 1984.

RESULTS (expected)

- Quantitative comparison of anthropogenic and natural nitrogen on three forested watersheds.

PRODUCTS

- Report; Data are to be applied to other projects.

Effects of Acid Precipitation on Agricultural Crops - Northeast RP1812

OBJECTIVE

- Measure effects of acid precipitation on productivity of northeastern U.S. crops.

APPROACH

- Field experiments.
- Environmental chambers.
- Simulated precipitation.

CONTRACTOR

- Boyce Thompson Institute for Plant Research.

STATUS

- In progress.

PROJECT TERM

- 1980 - 1983.

RESULTS

- In radish plants subjected to simulated acidic rain, rates of hydrogen ion deposition giving significant reductions in yield were about ten-fold greater than those rates now occurring in eastern North America.
- Dry deposition studies using uranine particles (0.08 μm diameter in concentrations of about 1.5×10^4 particles/cm^3) have shown that about 40% of the total particulate deposit was removed by the one-hour exposure to rain.
- No significant effects on yield were found down to pH 3.5.

PRODUCTS

- Data; Report.

Effects of Acid Rain on Nutrient Status of Forest Ecosystem - RP1813

OBJECTIVE

- o Evaluate effects of acid rain on soils, decomposer invertebrates, uptake and leaching in forest ecosystems, and the consequences relative to nutrient status and fertility of the soils.

APPROACH

- o Field plots (ORNL and UW).
- o Controlled perturbation (ORNL and UW).
- o Quantification of dryfall (SRL).

CONTRACTORS

- o Oak Ridge National Laboratory and University of Washington.
- o Savannah River Laboratory.

STATUS

- o Data collection completed; follow-on project in review.
- o Dryfall field experiments have begun.

PROJECT TERM

- o 1980 - 1984.

RESULTS

- o At the eastern study sites, acid precipitation was largely neutralized in the forest canopy and surficial soil layers.
- o At the western site, a continuous balance is attained between proton-generation and proton-consumption in the forest canopy, while a net generation of protons occurs in the deciduous forest soil.
- o At the eastern sites, S cycling was controlled by geochemical processes, while N cycling was controlled by biological processes.

PRODUCTS

- o Reports; Experimental techniques; Data sets.

Response of Agricultural Soils to Acid Precipitation - RP1904

OBJECTIVE

- Assess vulnerability of agricultural soils to acidic deposition.

APPROACH

- Literature survey.
- Workshop of invited participants who are experts in the field of research.

CONTRACTOR

- Battelle Columbus Laboratories.

STATUS

- Technical work completed; Final report published.

PROJECT TERM

- 1981.

RESULTS

- No in situ detrimental effect to soils or plants attributable to anthropogenic deposition with the exception of certain industrial sources (e.g., smelters) were observed.
- Standard agronomic practices offset the effects of acid deposition in virtually all cases.
- Some short-term fertilization effects have been observed.
- Percentage of sensitive soils is not great.
- No need for extensive EPRI research.

PRODUCTS

- Final report.

Acid Rain/Forest Canopy Interactions - RP1907

OBJECTIVE

- Evaluate interaction of wet and dry atmospheric deposition with deciduous forest canopy in terms of physical, chemical, and biological processes.

APPROACH

- Experimental watershed.
- Environmental chambers.

CONTRACTOR

- Oak Ridge National Laboratory.

STATUS

- Initial laboratory experiments complete.
- Second year of data collection complete.

PROJECT TERM

- 1981 - 1984.

RESULTS (expected)

- Quantitative assessment of the effect of canopy processes on the chemistry of through-fall deposition.
- Quantitative estimate of the contribution of dryfall to acidification.

PRODUCTS

- Report; Data sets.

Effects of Acid Precipitation on Agricultural Crops - Midwest and Southeast - RP1908

OBJECTIVE

- Measure effect of acid precipitation on productivity of midwestern and southeastern U.S. crops.

APPROACH

- Field experiments.
- Environmental chambers.
- Simulated precipitation.

CONTRACTORS

- Argonne National Laboratory.
- Oak Ridge National Laboratory.
- North Carolina State University.

STATUS

- Field arrays constructed.
- Data for year 1 taken.

PROJECT TERM

- 1981 - 1984.

RESULTS

- In greenhouse-grown soybean plants, injury to expanding leaves was induced by exposure to simulated rain of pH 2.6 and, to a lesser extent, pH 3.4. Growth inhibition resulted only from exposure to pH 2.6 rain.
- Productivity of forage plants increases with increased acidity, down to pH 3.5.
- Soil respiration was greatest at ambient pH levels. Soil respiration decreased with both increases and decreases in pH.

PRODUCTS

- Report; Data sets.

Effects of Acid Rain on Aquatic Processes: Methodology Development - RP1910

OBJECTIVE

- Develop a microcosm procedure for predicting effects of acidic deposition and toxic metals on lake ecosystems.

APPROACH

- Microcosm.

CONTRACTOR

- Lawrence Berkeley Laboratory, Western Aquatics, Inc., General Research Corp.

STATUS

- In progress.

PROJECT TERM

- 1981 - 1983.

RESULTS

- Improved aquatic microcosm protocol.
- Inventory of Acid Deposition Research Projects funded by the Private Sector (RP1910-3).
- Analyses of relationships among deposition, surface waters acidification and fish populations in North America.

PRODUCTS

- Data outputs for use in other projects; Microcosm methodology development; Reports.

Regional Integrated Lake Watershed Acidification Study
RP2174 (RILWAS)

OBJECTIVE

- Extend ILWAS methodology to regional scale evaluation.
- Test applicability of the lake acidification model in areas outside of the Adirondacks.
- Determine recent historical changes in lake acidity through sediment core analysis in multiple regions.

APPROACH

- Regional watershed studies model.
- Extension of the ILWAS study in NY state.
- ILWAS study to be conducted in Wisconsin.
- Test ILWAS model in watershed in western North Carolina.

CONTRACTORS

- Rensselaer Polytechnic Institute, Cornell University, University of Maine, Colgate University, Smith College, USGS, Syracuse University, Tetra Tech, University of Wisconsin, Wisconsin State Dept. of Natural Resources, Indiana University Foundation.

STATUS

- NY and Wisconsin field and laboratory programs are underway.
- ILWAS model is being calibrated for a western North Carolina watershed.

PROJECT TERM

- 1982 - 1985.

RESULTS (expected)

- Increased robustness and general applicability of ILWAS theory and model.
- Methodology for assessing vulnerability to acidification on a regional basis.

PRODUCTS

- Reports; Methodology to assess surface water vulnerability on a regional basis; Test of ILWAS model in area outside of Adirondacks.

Ecological Effects of Acidification and Aluminum on Streams - RP2326

OBJECTIVE

- Assess the effect of acidity and aluminum on stream biota.
- Determine the doses of Al and acidity that produce the observed responses.

APPROACH

- Field studies of behavior and effects of Al in streams.

CONTRACTOR

- Oak Ridge National Laboratory, Syracuse University, Cornell University.

STATUS

- Contracts initiated.

PROJECT TERM

- 1982 - 1985.

RESULTS (expected)

- Establish relationships among water acidity, aluminum content and aluminum bioavailability.

DELIVERABLES

- Reports; Open literature publications.

Lake Acidification Mitigation Project - RP2337

OBJECTIVE

- Evaluate the ecological soundness of liming for water-quality management in acidic areas.

APPROACH

- Evaluation of existing data.
- Field experiments.

CONTRACTOR

- General Research Corporation, Cornell University, Syracuse University, Clarkson College of Technology.

STATUS

- In progress.

PROJECT TERM

- 1983 - 1987.

RESULTS (expected)

- Compilation and preliminary analysis of overseas data.
- Collection of RILWAS-compatible water quality data set on limed lakes.
- Improved understanding of consequences of lake liming.

PRODUCTS

- Reports; Data sets; The Liming of Acidified Waters: Issues and Research: A report of the International Liming Workshop (a related report published by the Fish and Wildlife Service, U.S. DOI, report FWS/OBS-80/40.14, December, 1982).

Fisheries and Lake Acidification - RP2346

OBJECTIVE

- Assess the change in fish status that might follow any changes in lake water chemistry as a result of a change in precipitation acidity.
- Incorporate a fisheries component into the Regional Integrated Lake Watershed Acidification Study (RILWAS) RP2174.

APPROACH

- Field studies.
- Laboratory studies.
- Predictive model development.

CONTRACTOR

- University of Wyoming.

STATUS

- Work started 9/83.

PROJECT TERM

- 1983 - 1988.

RESULTS (expected)

- Model to predict fish population size in unacidified low conductivity waters.
- Definition of response of fish to different levels of pH, calcium and aluminum to modify input parameters to model.
- Validation of model application to acidified low conductivity waters.
- Determination of physiological parameter(s) which will predict relative sensitivity of fish species to conditions in acidified lakes.

PRODUCTS

- Reports; predictive mathematical model.

Aluminum Biogeochemistry of Forested Watersheds - RP2365

OBJECTIVE

- Define, on a multiregional basis, the biogeochemical linkages between acidic deposition, aluminum mobility, and forest vegetation.

APPROACH

- Controlled laboratory and field experiments.

CONTRACTOR

- University of Maine, Cornell University, Syracuse University, University of Minnesota, Colgate University, Smith College, University of Virginia, University of Missouri, Tennessee Valley Authority, State University of New York-Syracuse, University of Vermont.

STATUS

- In progress.

PROJECT TERM

- 1983 - 1986.

RESULTS (expected)

- Test of hypothesis on a multiregional basis that acidic deposition enhances the mobilization of Al in forest soils which in turn damages trees.

- Develop a general model of Al biogeochemistry of forested watersheds.

PRODUCTS

- Reports; data sets; model.

SO_2 and O_3 Effects on Crops - RP2371

OBJECTIVE

- Assess the effects of SO_2 and O_3 on forage, winter wheat, kidney bean, alfalfa, field corn, soybeans and potatoes in terms of both visible damage and yield-loss.

APPROACH

- Crop studies in open top chambers under varying conditions.

CONTRACTOR

- Boyce Thompson Institute for Plant Research, Argonne National Laboratory, Pennsylvania State University.

STATUS

- In progress.

PROJECT TERM

- 1983 - 1985.

RESULTS (expected)

- Develop dose-response equations for total seasonal yield.
- Measure photosynthesis rates over the season.
- Analyze growth parameters over the season.

PRODUCTS

- Report on findings.

ECONOMIC AND ENVIRONMENTAL INTEGRATION GROUP

The majority of EPRI's acid precipitation research is conducted by the Environmental Assessment Department of the Energy Analysis and Environment Division. However, the Economic and Environmental Integration Group under the EA&E Division Director also carries out some acidic precipitation work (Table 3). The Integration Staff is broken into two working groups: the Economic Integration Group and the Environmental Integration Group.

Economic Integration Group

This group has conducted one project on acidic precipitation. The objective was to develop a framework for cost-benefit analysis of emission control measures directed at controlling acidic precipitation. This short-term project has been completed. In order to develop this framework, cooperation within EPRI was important. Environmental data developed by EPRI's Environmental Assessment Department and emission control data from the Advanced Power Systems and Coal Combustion Systems Divisions were used in the data base for this analysis.

This research project was requested by UARG. Although EPRI is responsible for developing and testing the methodology, the actual application will be carried out by utility groups.

Environmental Integration Group

The objective of this group's precipitation research is to estimate the economic effects of selected damage caused by acidic deposition. This research addresses materials damage and crop damage from acidic precipitation. The approach has been to develop methodologies for measuring damage and to apply these methodologies to estimate the economic damage to materials and crops. Work will include economic effects of ecosystem damage as well.

In order to undertake and evaluate cost-benefit analyses (for environmental regulation), an estimate of damage costs is necessary.

Table 3

ECONOMIC AND ENVIRONMENTAL INTEGRATION GROUP
Acidic Precipitation Research

Research Project	Title	Project Term
ECONOMIC INTEGRATION GROUP		
RP2156	Acid Rain Issue Decision Framework for Evaluating Alternative Control Measures	1981-1982
ENVIRONMENTAL INTEGRATION GROUP		
RP1829	Economic Estimates of Ecological Damage	1980-1983
RP2071*	Materials Damage from Acid Deposition	1982-1983

*Funded by the Ecological Studies Program.

Economic Estimates of Ecological Damage - RP1829

OBJECTIVE

- Develop a methodology to measure the economic damage to ecosystems.
- Apply the methodology to estimate the economic damage to ecosystems from various pollutants.

APPROACH

- Literature review.
- Methodology development.

CONTRACTOR

- IR&T Corporation.

STATUS

- In progress.

PROJECT TERM

- 1980 - 1983.

RESULTS (expected)

- Estimate crop damage from SO_2 and O_3.
- State of knowledge on crop damage from acid deposition.
- Cost estimates of systems to neutralize acidic surface waters.

PRODUCTS

- Reports; Developed methodology.

COMMENTS

- Close communication maintained with the Ecological Studies Program in this research. Data from ES projects were used.

Materials Damage From Acid Deposition - RP2071

OBJECTIVE

- Derive estimates for materials damage from acidic deposition.

APPROACH

- Literature reviews.
- Construct damage functions.

CONTRACTOR

- Rockwell International.

STATUS

- Report being prepared.

PROJECT TERM

- 1982 - 1983.

RESULTS

- Literature review conducted.
- Feasibility of retrospective study on materials damage completed. Findings being reviewed.

PRODUCTS

- Report; Study design.

Acid Rain Issue Decision Framework for Evaluating Alternative Control Measures - RP2156

OBJECTIVE

- To develop a framework for evaluation of emission control and mitigation measures directed at controlling acidic precipitation.

APPROACH

- Develop a decision analysis model to evaluate alternative emission control strategies stressing both economic and environmental impacts.
- Develop methods of displaying the cost/benefit evaluations.

CONTRACTOR

- Decision Focus, Inc.

STATUS

- Technically complete; Final report published; Framework has been turned over to EEI.

PROJECT TERM

- 1981 - 1982.

RESULTS

- A cost/benefit framework to aid in 1) assessment of control and mitigation strategies, 2) evaluation of research programs to provide better information as a basis for better decisions.

PRODUCTS

- Analysis framework; Report; Computer model available from the Electric Power Software Center; Users' manual.

APPENDIX

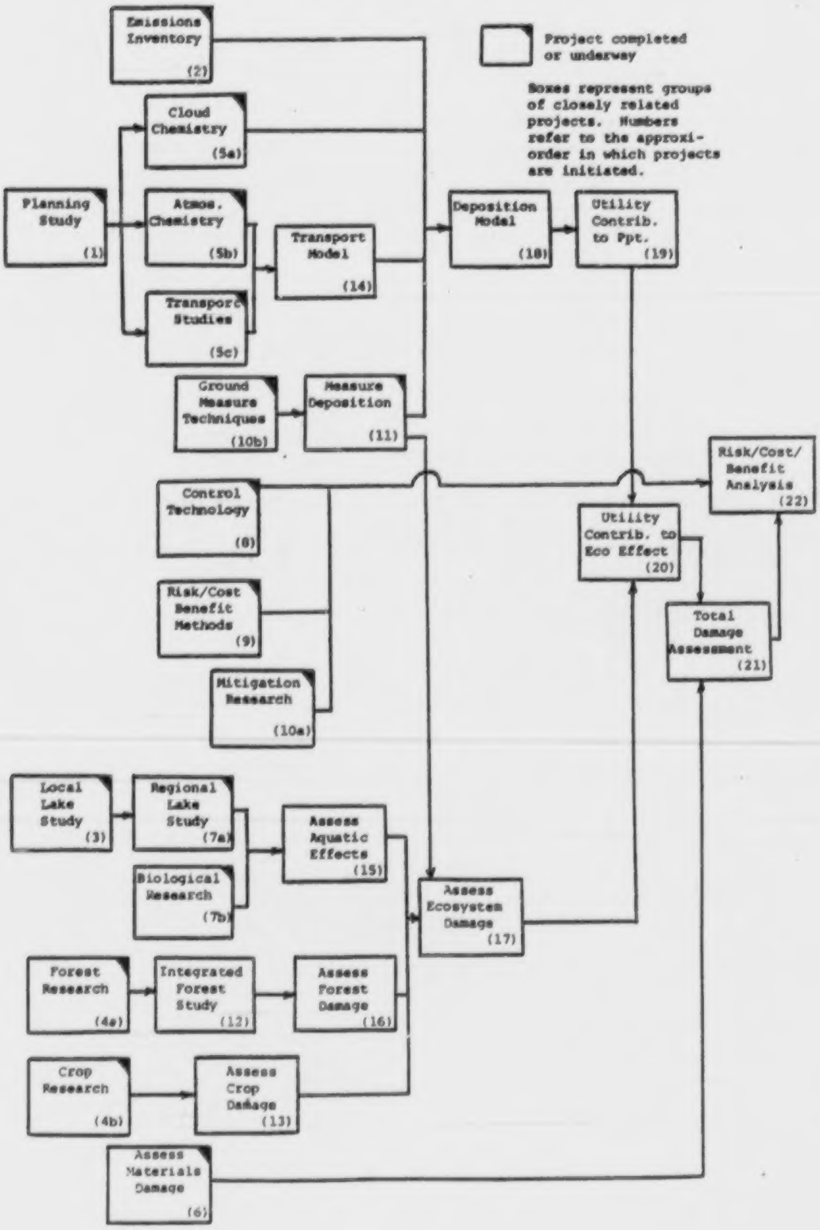
This appendix comprises three sections. The first section is a five-page strategy of EPRI's atmospheric deposition research. The flow diagram (box chart) on page 64 shows, from left to right, the sequence of research areas which lead to the final research objectives. This diagram illustrates the integration of acidic precipitation research within and among the various programs at EPRI. One-sentence descriptions of each box on the flow diagram are given on the second sheet. The specific group responsible for the research in each box is also indicated. Expenditures and future estimated costs for this work, through 1988, are given on pages 67 and 68.

During the course of research, new information may show that certain boxes can be eliminated or changed, or that an entire flow can be ended. These plans are by no means static. Reevaluation of research objectives and strategies is an ongoing process, with decision points coming after almost every box.

The second section is a table of EPRI acidic precipitation research costs. Costs have been broken down by project for the two programs and one integration group involved in the research. This table is the best estimate of costs for EPRI research in the area of acidic deposition (as of 10/13/83).

The final section is a listing of published EPRI acidic precipitation-related reports.

EPRI ACIDIC DEPOSITION RESEARCH


Emissions Inventory (2)
Project completed or underway
Boxes represent groups of closely related projects. Numbers refer to the approxi- order in which projects are initiated.
Cloud Chemistry (5a)
Planning Study (1)
Atmos. Chemistry (5b)
Transport Model (14)
Deposition Model (18)
Utility Contrib. to Ppt. (19)
Transport Studies (5c)
Ground Measure Techniques (10b)
Measure Deposition (11)
Risk/Cost/ Benefit Analysis (22)
Control Technology (8)
Utility Contrib. to Eco Effect (20)
Risk/Cost Benefit Methods (9)
Total Damage Assessment (21)
Mitigation Research (10a)
Local Lake Study (3)
Regional Lake Study (7a)
Assess Aquatic Effects (15)
Biological Research (7b)
Assess Ecosystem Damage (17)
Forest Research (4a)
Integrated Forest Study (12)
Assess Forest Damage (16)
Crop Research (4b)
Assess Crop Damage (13)
Assess Materials Damage (6)

EPRI ACIDIC DEPOSITION RESEARCH

The basic objective of this research is to identify the utility industry contribution to damage (ecological and material) that might result from acidic deposition. In addition, a risk/cost/benefit analysis will be undertaken - one that includes mitigation practices and control strategy at the power plant. (N.B. In the descriptions below, the initials in parenthesis indicate what group in EPRI is mainly responsible for the research. EPC = Environmental Physics & Chemistry Program; ES = Ecological Studies Program; E^2I = Environmental Physics & Chemistry Program; ES = Ecological Studies Program; E^2I = Energy & Environmental Integration Staff; CS = Coal Combustion Systems Division).

1. Through planning studies, assess the research needed to achieve the goal represented by Box 19 (EPC).

2. Compile an emissions inventory (EPC).

3. Initiate research on the physical and chemical processes related to lake acidification - ILWAS (ES).

4a. Study the effects of individual pollutants on forests (ES).

4b. Initiate research on the effects of acidic deposition on crops (ES).

5a. Study the in-cloud processes that lead to the formation of acidic precipitation (EPC).

5b. Conduct field and laboratory research on chemical reactions which occur in the atmosphere - emphasis on NO_x and SO_x oxidation (EPC).

5c. Study transport of pollutants - particularly long-range transport (EPC).

6. Assess damage to materials from acidic deposition (E^2I).

7a. Based on the findings of #3, develop techniques (especially models) which allow an assessment of lake sensitivity to acidification on a regional basis (ES).

7b. Incorporate into the lake studies (#3, 7a), a biological component (ES).

8. Conduct research on control and reductions of SO_x, NO_x emisisons (CCS).

9. Develop methods for conducting risk/cost/benefit analyses related to acidic deposition damage and control (E^2I).

10a. Conduct research on mitigating aquatic and terrestrial effects of acidic deposition (ES).

10b. Develop methods for measuring the deposition of acidic substances, emphasis on dry deposition (EPC).

11. Using methods developed in #10b, measure both wet and dry deposition (EPC, ES). N.B. Much data on deposition comes from programs other than EPRI.

12. From #4a, conduct an integrated forest study (ES).

13. From #4b, assess the effects to crops from acidic deposition (ES).

14. From the data generated in #5b, 5c, improve existing or develop new pollutant transport models (EPC).

15. From #7a, 7b, assess the overall effect to aquatic systems from acidic deposition (ES).

16. From #12, assess the effect on forests from acidic deposition (ES).

17. Combining information from the effects studies (#13, 15, 16) with data on deposition (#11), assess the overall effect on ecosystems from acidic deposition (ES).

18. Using the transport model (#14) along with information on emissions (#2) and deposition (#11), develop a deposition model which relates emissions to deposition of acidic substances (EPC).

19. From #18, assess the utility contribution to acidic deposition (EPC).

20. Combining the information from #17 and #19, assess the utility contribution to ecosystem effects (EPC, ES, E^2I).

21. Combining information from #20 with an assessment of materials damage (#6), evaluate the utility contribution to overall effects that may be related to acidic deposition (EPC, ES, E^2I).

22. Using information from #8, 9, 10a, 21, conduct a risk/cost/benefit analysis (E^2I).

EPRI ACIDIC DEPOSITION RESEARCH
Budget through 1988
($ Thousands)

Box #	RP #	Through 1983	1984	1985	1986	1987	1988
1.	WS78-98	50					
	RP1630-35	Funding listed under #5c					
2.	RP862-5	325					
	RP1630-23	Funding listed under #5c					
3.	RP1109	4,905					
	RP1910	1,042					
4a.	RP1632	172					
	RP1727	403	120	25			
	RP1813	855	300	185			
	RP1907	501	200	300	200	200	200
4b.	RP1812	434	150				
	RP1904	70					
	RP1908	1,879	345	100	300	200	100
	RP2371	616	240	280			100
5a.	RP1311	1,740					
	RP2022	70					
4a.	RP2023	1,569	665	500			
5b.	RP1434	1,147					300
	RP1630-12	Funding listed under #5c					
	RP2375	82					
	EP0735					500	400
5c.	RP862*	(7,779)*					
	RP1311	Funding listed under #5a					
	RP1630	2,584	4,850	3,850	2,600	3,600	3,600
	RP2370	725	260				
	RP2434	386	300	2,000	5,600	5,100	2,800
6.	RP1829	364	10	100	100	200	100
	RP2071	131	50	100	200	300	300
7a.	RP2174	2,004	1,400	1,000	900	900	300
7b.	RP2346	161	600	620	640	500	500
	RP2326	640	700	890	450	500	800
8.		Funding by CCS Division					
9.	RP2156	308	200	300	300	300	200

EPRI ACIDIC DEPOSITION RESEARCH (continued)
Budget through 1988
($ Thousands)

Box #	RP #	Through 1983	1984	1985	1986	1987	1988
10a.	RP2337	374	900	1,000	1,000	1,000	1,000
	EP0764			300	300	300	500
10b.	RP1155	350					
	RP1306	154					
	RP2264	165	80	9			
	EP0737						400
	EP0751						100
11.	RP1155	Funding listed under #10b					
	RP1376	498					
	RP1630-2	Funding listed under #5c					
12.	RP2365	446	800	740	760	500	800
	EP0761		50	200	400	400	400
13.	RP1908	Funding listed under #4b					
	RP2371	Funding listed under #4b					
14.	RP1630-13	Funding listed under #5c					
	RP1630-21	Funding listed under #5c					
	RP2199	159	300	300	500	500	600
15.	RP2346	Funding listed under #7b					
	EP0763			100	100		
16.	EP0761	Funding listed under #12					
17.	EP0762			400	600	1,200	2,000
18.	RP1630-21	Funding listed under #5c					
19.		Funding after 1988					
20.		Funding after 1988					
21.		Funding after 1988					
22.	RP2156	Funding listed under #9					
	TOTAL	25,309	12,520	13,299	14,950	16,200	15,500

*Project has an acidic deposition component but was not started specifically as an acidic deposition project. Costs are not included in the total.

as of 10/13/83

ACIDIC DEPOSITION RESEARCH AT EPRI
($000)

PROJECT NO.	SHORT TITLE	through 1983	1984	1985	1986	1987	1988
			- - - - - - -	-PLANNED EXPENDITURES-	- - - - - - -		
Environmental Physics and Chemistry Program							
WS78-98	Formation of Acid Precipitation Workshop	50					
RP862	SURE (-5 Emissions Inventory)	325					
RP1155	Acidic Precipitation in Adirondacks	350					
RP1306	Dry Deposition Model	154					
RP1311	North Sea Study	1,740					
RP1376	Precipitation Monitoring Network	498					
RP1434	SO_x Night Chemistry	1,147					300
RP1630	RAQS/RAQS-2 related portion includes: -2 Precipitation Monitoring Network -12 Cloudwater-Rainwater Chemistry -21 RAQ Model Development -23 Emissions Inventory -26 Dry Deposition Intercomparison Study -35 Workshop/Research Needs	2,584	4,850	3,850	2,600	3,600	3,600
RP2022	Storm Model	70					
RP2023	In-Cloud Chemistry	1,569	665	500			
RP2199	Receptor Modeling	159	300	300	500	500	600
RP2264	Sulfate Deposition During SURE	165	80	9			
RP2370	CAPTEX	725	260				
RP2375	Measuring Atmospheric H_2O_2	82					
RP2434	MATEX	386	300	2,000	5,600	5,100	2,800
EP0735	Cloud Kinetics					500	400
EP0737	Dry Deposition						400
EP0751	Precipitation Analyzer						100
	PROGRAM TOTAL	10,004	6,455	6,659	8,700	9,700	8,200
Ecological Studies Program							
RP1109	ILWAS	4,905					
RP1632	Microcosm Evaluation	172					

as of 10/13/83

PROJECT NO.	SHORT TITLE	PLANNED EXPENDITURES through 1983	1984	1985	1986	1987	1988
RP1727	NO_x in Forests	403	120	25			
RP1812	Acid Precipitation/Crops (NE)	434	150				
RP1813	Acid Precipitation/Forest Nutrients	855	300	185			
RP1904	Acid Precipitation/Agric. Soils	70					
RP1907	Acid Precipitation/Forest Canopy	501	200	300	200	200	200
RP1908	Acid Precipitation/Crops (MW/SE/SW)	1,879	345	100	300	200	100
RP1910	Acid Precipitation/Aquatic Processes	1,042					
RP2071	Materials Damage	131	50	100	200	300	300
RP2174	RILWAS	2,004	1,400	1,000	900	900	300
RP2326	Al/H^+: Streams	640	700	890	450	500	800
RP2337	Mitigation Studies	374	900	1,000	1,000	1,000	1,000
RP2346	Fisheries and Lake Acidification	161	600	620	640	500	500
RP2365	Al Biogeochem. in Forests	446	800	740	760	500	800
RP2371	SO_2 and O_3 Effects on Crops	616	240	280			100
EP0761	SO_x/H^+ Forest Effects		50	200	400	400	400
EP0762	Integrated Field Studies			400	600	1,200	2,000
EP0763	Ground Water Effects			100	100		
EP0764	Terrestrial Mitigation			300	300	300	500
	PROGRAM TOTAL	14,633	5,855	6,240	5,850	6,000	7,000
Economic and Environmental Integration Staff							
RP1829	Economic Estimates Ecol. Damage	364	10	100	100	200	100
RP2071	Materials Damage (Funded by the Ecological Studies Program)						
RP2156	Decision Framework/Control Measures	308	200	300	300	300	200
	PROGRAM TOTAL	672	210	400	400	500	300
	TOTAL	25,309	12,520	13,299	14,950	16,200	15,500

EPRI Reports Related to Acidic Precipitation (as of 10/83)

1.	EPRI	EA-79-6-LD Ecological Effects of Acid Precipitation Workshop Proceedings CERL December 1979	SOA 77-403
2.	EPRI	EA-1066 Implementation and Coordination of the Sulfate Regional Experiment (SURE) and Related Research Programs Environmental Research & Technology, Inc. Interim Report, May 1979, 203 pp.	RP862
3.	EPRI	EA-1074 Proceedings: Advisory Workshop to Identify Research Needs on the Formation of Acid Precipitation Sigma Research, Inc. Workshop Report, May 1979, 290 pp.	WS 78-98
4.	EPRI	EA-1452 Modeling of Dry Deposition of SO_2 and Sulfate Aerosols Aeronautical Research Associates of Princeton, Inc. Final Report, July 1980, 88 pp.	RP1306-1
5.	EPRI	EA-1650-SR Regional Air Quality Studies: The Needs and the Priorities EPRI Special Report, February 1981, 82 pp.	RP1630
6.	EPRI	EA-1682-SR Rationale for Quality Precipitation Chemistry Sampling EPRI Special Report, January 1981, 78 pp.	
7.	EPRI	EA-1825 The Integrated Lake-Watershed Acidification Study (ILWAS)--Contributions to the International Conference on the Ecological Impact of Acid Precipitation Tetra Tech, Inc. Interim Report, May 1981, 126 pp.	RP1109-5
8.	EPRI	EA-1826 Characterization of Acidic Precipitation in the Adirondack Region Rensselaer Polytechnic Institute Final Report, May 1981, 208 pp.	RP1155
9.	EPRI	EA-1901 v. 1, 2 & 3 The Sulfate Regional Experiment: Report of Findings Environmental Research & Technology, Inc. Final Report, March 1983, v. 1 354 pp., v. 2 238 pp., v. 3 396 pp.	RP862-1, RP862-2

10. EPRI EA-1902 Documentation of SURE RP862-2
Sampling Sites
Environmental Research and Technology, Inc.
Supplemental Report, June 1982, 108 pp.

11. EPRI EA-1904 The Sulfate Regional Experiment: RP862-2
Data Base Inventory and Summary of
Major Index File Programs
Environmental Research and Technology, Inc.
Interim Report, August 1982, 124 pp.

12. EPRI EA-1907 The Sulfate Regional Experiment: RP862-2
Regional Air Quality Modeling Documentation
Environmental Research and Technology, Inc.
Interim Report, August 1982, 194 pp.

13. EPRI EA-1909 Aircraft Measurements of Pollutants RP862-3
and Meteorological Parameters During the
Sulfate Regional Experiment (SURE) Program:
Meteorology Research, Inc.
Meteorology Research, Inc.
Final Report, April 1981, 240 pp.

14. EPRI EA-1910 v. 1-6, Aircraft Data Summaries RP862
for the SURE Intensives
Meteorology Research, Inc.
Research Triangle Institute

15. EPRI EA-1911 Tables of Statistical Summaries RP862
for the SURE Aircraft Measurements
Meteorology Research, Inc.
Final Report, September 1981, 220 pp.

16. EPRI EA-1912 Aircraft Measurements of Pollutants and Meteorological Parameters During the RP862-4
Sulfate Regional Experiment (SURE) Program:
Research Triangle Institute, Inc.
Research Triangle Institute, Inc.
Final Report, April 1981, 198 pp.

17. EPRI EA-1913 Emissions Inventory for the RP862-5
SURE Region
GCA Corporation
Final Report, April 1981, 304 pp.

18. EPRI EA-1914 v. 1, Eastern Regional Air Quality RP1630-1
Measurements
Environmental Research and Technology, Inc.
Final Report, September 1982, 200 pp.

19. EPRI EA-1914 v. 2 Precipitation Scavenging RP1630-1
Chemistry for Sulfate and Nitrate from the
SURE and Related Data
Environmental Research and Technology, Inc.

Final Report, February 1983, 68 pp.

20. EPRI EA-2273 Proceedings: Ecological Effects of Acid Precipitation WS 80-180
Sigma Research, Inc.
February 1982, 104 pp.

21. EPRI EA-2362 Feasibility Study to Utilize Liming as a Technique to Mitigate Surface Water Acidification RP1109-14
General Research Corporation
Interim Report, April 1982, 116 pp.

22. EPRI EA-2508 Response of Agricultural Soils to Acid Deposition RP1904-1
Battelle, Columbus Laboratories
Proceedings, July 1982, 150 pp.

23. EPRI EA-2540 Acid Deposition: Decision Framework. Volume 1: Description of Conceptual Framework and Decision Tree Models RP2156
Decision Focus Incorporated
Final Report, August 1982, 122 pp.

24. EPRI EA-2827 The Integrated Lake-Watershed Acidification Study: Proceedings of the ILWAS Annual Review Conference RP1109-5
Tetra Tech, Incorporated
Proceedings, January 1983, 348 pp.

25. EPRI EA-2889 Inventory of Acid Deposition Research Projects Funded by the Private Sector RP1910-3
General Research Corporation
Final Report, February 1983, 358 pp.

26. EPRI EA-3096 Dry Deposition Field Studies RP1630-26
Battelle, Pacific Northwest Laboratories
Final Report, May 1983, 132 pp.

27. EPRI EA-3127 v. 1 & 2 An Assessment of the Relationship Among Acidifying Depositions, Surface Water Acidification, and Fish Populations in North America RP1910-2
Western Aquatics, Inc.
Final Report, June 1983, v. 1 176 pp., v. 2 (bibliography) 302 pp.

28. EPRI EA-3221 The Integrated Lake-Watershed Acidification Study, Volume 1: Model Principles and Application Procedures RP1109-5
Tetra Tech, Inc.
Final Report, September 1983, 214 pp.

29. EPRI EA-3217 The Fate of Atmospheric Emissions Along Plume Trajectories Over the North Sea--Summary Report RP1311-1
Central Electricity Research Laboratories
Final Report, September 1983, 162 pp.

Senator **Warner**. Are we in possession of information that confirms that your institute found some of the lakes in the Adirondacks to have had a history of acid rain that goes back to, shall we say, before the Indians?

Dr. **Perhac**. Well, we have studied one lake where we have done some studies on dating, and the indications there are that the lake—this is Woods Lake in the Adirondacks—has been acidic for perhaps a hundred years or more.

But, in addition, a Professor Whitehead from the Indiana University, under the auspecies of the National Science Foundation, has studied some lakes which he ascribes an acidity back to about 8 or 9,000 years.

So the answer to your question is yes, some have been acidic for a long time; how many we just don't know.

Senator **Warner**. Thank you very much.

[Subsequent to the hearings the following questions were submitted to Dr. Perhac, and answers received:]

JAMES A. McCLURE, IDAHO, CHAIRMAN
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United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

Dr. Ralph M. Perhac
Deputy Director
Energy Analysis and Environmental Division
Electric Power Research Division
P.O. Box 10412
Palo Alto, California 94303

Dear Dr. Perhac:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Dr. Ralph M. Perhac
by the Committee on Energy and Natural Resources

Oversight Hearing on Implementation of the Acid Precipitation Act of 19

1. I understand that EPRI has studied the acidification of the Adirondack Lakes and found some of them to have been acidified for hundreds and, perhaps, even thousands of years. Is this true?

2. What do you believe is the relationship between the various sources of acidity that contribute to the lake acidification process? By this question, I am particularly interested in whether acid deposition is always the principle contributor of acid to lakes and streams in the northeastern United States.

3. In EPRI's lake acidification work, have you developed a means to predict the effect a change in acidic deposition will have on the acidity level of a lake? If so, what effect will a 50% change in the amount of acid deposition have on lake acidity?

4. In your judgment, should the Federal government increase its commitment to the development of new clean coal-burning technologies -- including financial assistance for the commercialization of these emerging technologies?

Answers to

Questions Submitted To Dr. Ralph M. Perhac
Deputy Director
Energy Analysis and Environmental Division
Electric Power Research Institute

From
Committee on Energy and Natural Resources

Hearing on Acid Rain
April 30, 1984

ELECTRIC POWER RESEARCH INSTITUTE

Richard

MAY 21 1984

Official Committee File

EPRI

May 15, 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
MAY 21 1984
WASHINGTON, D.C. 20510

The Honorable James A. McClure
United States Senate
Washington, DC 20510

Dear Sir:

I have your letter of May 10, 1984 and the questions you attached to it. I am pleased to have the opportunity to respond to your inquiry. Likewise, I was honored to be asked to testify before your committee on April 30, 1984.

1. EPRI's study has not yet identified lakes in the Adirondacks which have been acid for thousands of years. One of the original three lakes we studied (Woods Lake) apparently has been acidic for well over 100 years. Professor Whitehead (Indiana University), under support from the National Science Foundation, studied a number of lakes in the Adirondacks and reported in the literature that some have been acidic (based on diatom paleolimnology) for about the past 8000 or 10,000 years, i.e., since the end of the last glaciation.

2. From our limited, but intensive, study in the Adirondacks, we find that atmospheric input is only one factor which may have a bearing on lake acidity. The overall characteristics (especially physical and chemical properties of soil) probably play the major role.

3. From our Adirondack study, we have developed a model which simulates lake behavior. Using this model on, e.g., Panther Lake (pH of about 7.0), we find that either a doubling or halving of the atmospheric input of sulfur produces a change in lake acidity that is just beyond our measuring capabilities, i.e., a change of only 0.1 or 0.2 of a pH unit. Incidentally, such changes in atmospheric deposition are, of course, extreme.

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The Honorable James A. McClure Pg. 2

4. This question is one which involves policy decisions, and, as an EPRI employee, I prefer, with your permission, not to become involved in policy issues.

Thank you again for the opportunity to comment and to testify. We are always at your service.

Respectfully,

Ralph M. Perhac
Director
Environmental Assessment Department

RMP:bp

Senator **Warner**. We will now hear from Dr. Dale Johnson, speaking on forest effects.

STATEMENT OF DR. DALE W. JOHNSON, RESEARCH STAFF MEMBER, ENVIRONMENTAL SCIENCES DIVISION, OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TN

Dr. **Johnson**. Thank you, Mr. Chairman.

By way of background, I am a forest soils scientist from Oak Ridge National Laboratory in Tennessee. And I, too, like Dr. Perhac, would like to just summarize a few key points here rather than reading my testimony on the whole.

My first point is to echo pretty much what Jerry Schnoor was saying, that our understanding of the important processes is improving rapidly, we now know that we must follow the fate of sulfur and nitrogen closely in the system as they cycle and move through forest systems, rather than focusing exclusively on rain pH or through fall pH in itself.

In many ways, the fate of sulfur and nitrogen are more important than the pH of rainfall in determining the effects on both terrestrial and aquatic systems, including acidification effects.

My second major point is that I think it's helpful to put these effects into basically two categories; one I would call capacity effects, and the second would be intensity effects.

Effects on the capacity parameters, an example of that would be soil acidity, are very slow because there's a very large pool of soil acidity, and it's difficult to change. And these are in contrast to intensity factors; an example of which would be the pH sulfate, calcium and aluminum concentration in solution which can change quite rapidly in responses to atmospheric inputs.

Each must be put within the context of the natural acidifying processes that occur in any forest system. So we're not talking about brandnew additions of acid from the atmosphere, but an incremental addition, whose quantity must be estimated and put in perspective of natural processes.

The question of reversibility has been brought up several times. And I would concur with Jerry Schnoor on this, that both the capacity and the intensity effects that I referred to are reversible. And the intensity effects would be fairly rapidly reversible as soon as you remove the ions from solution or ions from precipitation.

The capacity effects would, of course, take much longer to manifest themselves. Changes in soil acidity may take, as Dr. Perhac said, from hundreds to thousands of years, it would be slower to reverse themselves.

And a third major point I'd like to make is that we now are coming close to a consensus among soil and aquatic scientists as to the appropriate mechanisms relating to surface water acidification. And this has been a rather new phenomenon within the last 5 years, and some real progress in theory in this regard.

It is thought to be primarily a function of the movement of strong acid anions, like sulfate and nitrate through a soil that is already acid, and in this sense it doesn't matter whether the sulfate and nitrate come in as a calcium, a neutral salt or an acid, the presence of the anion in an acid soil seems to be the key.

However, we do not know the actual magnitudes of these effects, and we do not know, but are rapidly learning, as Jerry Schnoor pointed out, the scope, the geograpical extent to which these processes do acidify lakes.

We do have a handle on the mechanisms, however. Oh, and one very important lack still in this area is the rate of soil weathering. And by that I mean the rate at which the soil can regenerate neutralizing base cations like calcium and magnesium to exchange sites. This is an unknown area at this point in need of research.

As far as the forest effects, at this time we have no consensus as to what acid deposition does to the forest, because we do not simply know the mechanisms of damage. And we have correlated information that some trees die or grow more slowly in areas receiving acid deposition, but no cause effect relationships have been established, and none will until we have process level and system level research on the specific causes.

It may well be that the two phenomena, acid rain and forest decline, are unrelated; in which case, we have another problem to address, the actual cause of the forest decline. And again, only process level research will be able to address this question.

Thank you.

[The prepared statement of Dr. Johnson follows:]

Statement of
Dale W. Johnson
Research Staff Member
Environmental Sciences Division
Oak Ridge National Laboratory
Oak Ridge, Tennessee

Before the Committee on Energy and Natural Resources
United States Senate

April 30, 1984

EFFECTS OF ACID DEPOSITION ON FOREST SOILS AND NUTRITION

Mr. Chairman and Members of the Committee:

I am a research staff member of the Environmental Sciences Division of Oak Ridge National Laboratory where I have been employed for the past seven years. I have a Ph.D. in forest soils and nine years research experience (resulting in over 50 publications) in soil and tree nutritional aspects of acid deposition as well as fertilization, harvesting, and nutrient cycling in forest ecosystems. I am currently responsible for acid deposition research projects funded by the Electric Power Research Institute and the Environmental Protection Agency, both of which involve collaboration with forest soil scientists at several other institutions throughout the United States.

I would like to very generally describe what is now known as to the fate of acid deposition in forest ecosystems and its effects on natural waters, forest soils, and tree nutrition. Specifically, I will describe the important processes governing the absorption, release, and transport (leaching) of sulfur, nitrogen, and hydrogen ions (acid) through forest ecosystems and the effects of these processes on water chemistry, soil chemistry and tree nutrition.

Acid deposition, contains both acid (H^+) and the essential plant nutrients, sulfur and nitrogen in forms readily available to plants (SO_4^{2-} and NO_3^-). In terms of soil acidification and plant nutrition, sulfur and nitrogen are in many ways more important than acidity in itself for several reasons. Many of us find it useful to conceptualize the process of soil leaching (transport of elements via solution) as a function of the inputs, production, and mobility of anions (negatively charged ions such as sulfate, nitrate, and naturally produced bicarbonate). If the anion associated with acid deposition (sulfate or nitrate) is not adsorbed by soils or taken up by forest biota, then acid deposition will cause an immediate increase in the leaching of base cations (such as calcium, potassium, and magnesium) from soils. In extremely acid soils, readily available base cation reserves are low (by definition) and aluminum will be mobilized and leached as well. The aluminum so mobilized may affect plant roots and/or be transported to lakes and streams where it may produce undesirable effects.

The leaching effects referred to above occur immediately when inputs of sulfate or nitrate add significantly to the natural levels of anions (mostly bicarbonate and organic anions) in soil solution. These effects will also disappear rapidly if added sulfate and nitrate are removed. Some investigators (J. O. Reuss, B. Ulrich) refer to these short-term responses as "intensity" factors, and they generally affect concentrations in solution. On the other hand, "capacity" factors generally refer to concentrations in solids (for example, the sulfur, nitrogen, base cation, aluminum, and acidity in soils), and these capacity factors change much more slowly than intensity factors in response to changing atmospheric inputs. A useful analogy might be the amount of money in one's wallet (intensity factor) vs reserves in checking and savings accounts (capacity factors).

Capacity and intensity factors interact in important, often predictable ways which determine ecosystem response to acid deposition. Soil solution sulfate and nitrate concentrations (intensity factors) will increase only after the biological and chemical capacities of an ecosystem to accumulate atmospherically deposited sulfur and nitrogen are reached. Since plants require 14 times as much nitrogen as sulfur, biological sulfur requirements are exceeded much more quickly than biological nitrogen requirements. Many temperate-zone forests in North America and Scandinavia are deficient in nitrogen and accumulate most atmospherically deposited nitrogen. On the whole, this is beneficial in terms of nitrogen status but may have undesirable side effects such as reduced frost tolerance, root mycorrhizal development, etc. Northern or subalpine forests have lower nitrogen requirements and some subalpine forests in North America receive higher nitrogen inputs than temperate forests so the potential for nitrogen saturation exists in those cases. When nitrogen saturation occurs, nitrate is produced in soils and thus nitrate-mediated leaching is increased. While there is scattered evidence that this may be occurring, only forthcoming nutrient cycling studies will take us beyond the stage of speculation in this matter.

When biological sulfur requirement is exceeded, as is frequently the case in forests receiving acid deposition, sulfur may be retained by soil organic complexes and by sulfate adsorption to subsurface soils. We have found that as a very general rule, soils typical of northeastern forests (Spodosols) adsorb less sulfate than soils typical of southeastern forests (Ultisols). This pattern is generally consistent with sulfate input-output budgets which show most northeastern forests either in balance or showing a slight net loss of sulfate and southeastern forests accumulating sulfate.

One of the most important capacity factors for acid deposition effects on forest soils is soil acidity. There is no doubt that sufficiently high inputs of acid can acidify forest soils. It is not easy to define those "sufficiently high inputs," however, since one of the most crucial processes, soil weathering, cannot be easily quantified. Weathering in this context refers to the replenishment of available, or, more precisely, exchangeable base cations from non-exchangeable soil reserves. It is a crucial process because it actually determines the degree to which soils can be acidified by acid deposition. That is, if acid deposition-accelerated leaching exceeds weathering, soils will acidify and if weathering keeps pace with leaching, no acidification will occur. Our estimates of time lags for soil acidification range from a few decades to centuries, but all estimates are very uncertain (and probably too short) because rates of weathering are unknown. Furthermore, we have reason to believe that weathering is stimulated or accelerated by increased acid inputs. It is important to note, however, that aluminum concentration and acidity in the soil solution phase (intensity factors) can be increased over short time periods without changing aluminum concentration and acidity in the soil solid phase (capacity factor). This will occur in extremely acid soils when soil solution sulfate or nitrate concentrations increase (after ecosystem sulfur or nitrogen retention capacity is exceeded). This soil solution intensity effect will occur whether sulfate or nitrate enter the system as acids or neutral compounds. Thus, hypotheses as to aluminum toxicity to tree roots have a basis in soil chemical theories in that we can envision aluminum mobilization from extremely acid soils (such as Spodosols in the northeastern United States) over a short period simply as a result of sulfate and nitrate leaching. Whether aluminum toxicity is the cause for tree damage remains to be established, however, since toxicity levels for most trees are as yet unknown. Aluminum toxicity to trees is the focus of much intense research at this time.

We have learned much over the last five years as to the mechanisms by which aluminum and acidity can be transported through soils to lakes and streams. Knowing these mechanisms, we can focus and refine our efforts toward quantifying the effects of various atmospheric loadings on lake and stream acidity (i.e., through simulation modeling). We are far from that point in terms of forest effects, however, since the mechanisms of damage (if indeed there is any significant forest damage due to acid deposition) are unknown. Many hypotheses exist as to the mechanisms of damage, one of which is the aluminum toxicity hypothesis described above. Others include foliar damage by gaseous pollution, excess foliage leaching, and carbohydrate imbalances caused by excessive nitrogen inputs. These hypotheses are now being tested at various institutions in this country, Canada, Europe, and Scandinavia.

The verdict as to acid deposition effects on forests must await thorough and objective testing of multiple hypotheses until the important mechanisms causing the damage are found. If these mechanisms are driven by or respond to acid deposition, we can focus our attention on the levels of deposition that can be tolerated. On the other hand, if the damage mechanisms are not affected by acid deposition (e.g., drought, pathogens), we have a separate problem to address.

Research sponsored by the Electric Power Research Institute (RP1813-1), the National Science Foundation's Ecosystem Studies Program (DEB-7824395), and the Office of Health and Environmental Research, U.S. Department of Energy, under contract No. DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

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Senator **Warner**. Thank you, Dr. Johnson.
Dr. Enoch.

STATEMENT OF DR. HARRY G. ENOCH, DIRECTOR, ENVIRONMENTAL AND TECHNOLOGY ASSESSMENT, KENTUCKY ENERGY CABINET

Dr. **Enoch**. Good afternoon, Mr. Chairman.

I'm Harry Enoch of the Kentucky Energy Cabinet. I would like to summarize my written testimony.

I want to comment on the acid rain control bill passed by the Senate Committee on Environment and Public Works.

One of the stated purposes of the bill is to stop the harmful effects of acid rain. And this is quite simply what most people have come to expect, a quick fix to our acid rain problems at minimal cost.

What will it cost? Implementing large sulfur dioxide emission reductions will be felt in the form of increased electricity rates and disruption of traditional coal markets, and subsequent disruption of regional economies in certain coal mining areas.

We have estimated the annual cost for Kentucky at between $376 and $700 million, depending on whether fuel switching, or retrofit scrubbers was adopted as a control strategy.

The corresponding increase in electricity rates is 17 to 32 percent.

Since fuel switching appears to be the cheaper alternative over the shortrun, many States will likely use this strategy to reduce emissions.

Over 80 percent of the coal produced in Kentucky is used in other States. Fuel switching by those States could lead to the loss of between 14,000 to 60,000 jobs in Kentucky.

What will the bill achieve? Although it seeks to address the acid rain and interstate pollution problems, the bill does not provide a rational solution to either.

It is, rather, a bill to reduce sulfur dioxide emissions largely from large utility boilers, mainly in a few Midwestern States.

The bill fails to reduce sulfur emissions from other sources; fails to reduce nitrogen emissions from any sources, and fails to reduce any emissions at all in 19 States. The resulting effect will be at best a discouragingly small improvement in the problem.

A 10-million-ton sulfur dioxide reduction might result in an increase in the average eastern pH from 4.2 to 4.3, or about a 20-percent reduction in acidity.

The improvement will be less in sensitive areas of the Northeast than in the Midwest, where the bulk of the emission reductions are targeted.

This, then, is not a solution to the acid rain problem, but a very small first step.

We question whether it will be a step in the right direction or not. We'd like you to consider the options.

Scrubbers, one of the options, can reduce sulfur emissions significantly. Retrofitting new equipment on old plants is not the most efficient technical solution to emission problems.

Retrofitting scrubbers will encourage old plants to be kept on line much longer, delaying their replacement with cleaner units. Any benefits then will come at the expense of greater long-term reductions.

Fuel switching would have a similar effect. Low-sulfur fuels are not the ultimate solution. Clean technology is. Fuel switching offers only very limited sulfur reductions, while clean technology offers unlimited reductions.

Requiring or encouraging the use of clean fuels will discourage the development and application of new technologies.

Fuel switching will also result in high-grading of coal resources. High-grading is selectively seeking out the highest quality fuels for use today, leaving behind lower quality fuels for tomorrow's users.

Another effect of high-grading is that lower-quality coals will be spoiled and wasted in the process of going after the high-quality coal. This is poor conservation of our national energy resources, and it will become worse when even lower-sulfur coals are being sought.

Kentucky is committed to solving the acid rain problem. We differ with our critics mainly in the nature of the solutions.

I believe that there is general agreement that we need to encourage the replacement of oil plants with clean, new technologies.

The development of cleaner ways to use coal has been a major goal in Kentucky for over 10 years. In 1974, under then Governor, Wendell Ford, Kentucky adopted a policy to promote the development and demonstration of environmentally acceptable technologies for the conversion of coal into clean fuels.

We established a $55 million trust fund, a $30 million bonding authority, and have spent $47 million on energy research. All of these are State funds.

The proposed legislation would accelerate emission reductions at great cost, and at the risk of discouraging or delaying the development of the new technologies.

We would like to propose the following as an alternative to acid rain control legislation:

First, we ask acceptance of the fact that the acid rain solutions must, of necessity, be long-range, or long-term solutions. The public should not be led to expect a painless, quick fix to this problem. There simply aren't any.

Saddling one region of the country with major utility emission reductions is not the answer. The solution, ultimately, will require major and expensive reductions of sulfur and nitrogen emissions in all regions of the country.

Second, encourage vigorous enforcement of the current Clean Air Act. And, last, create a climate that encourages the development and commercial application of new technology.

And two of the incentives to this end would be the coal technology bill that is before the committee at this time. Another vehicle would be the Synthetic Fuels Corporation. Many of their aims are consistent with solving the acid rain problem.

Thank you, Mr. Chairman.

[The prepared statement of Dr. Enoch follows:]

STATEMENT OF
HARRY G. ENOCH, Ph.D.
DIRECTOR OF ENVIRONMENTAL AND TECHNOLOGY ASSESSMENT
KENTUCKY ENERGY CABINET

BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

APRIL 30, 1984

Good morning, Mr. Chairman and members of the Committee. I am Harry Enoch of the Kentucky Energy Cabinet, and I am pleased to be here today to present Kentucky's view on proposed acid rain control legislation, namely, the interstate transport and acid precursor reduction provisions of the 1984 Clean Air Act Amendments (S. 768).

We recognize acid rain as one of our Nation's major environmental problems. Kentucky is part of that problem. However, much uncertainty exists concerning the causes and effects of acid rain. The debate over this issue has led to state, regional, and even international polarization, to confusion of our citizens and to mounting pressure on Congress to act - to do something now.

The Senate Committee on Environment and Public Works has responded by passing an amendment to the Clean Air Act (Section 120 of S. 768). One of the stated purposes of the amendment is to protect the environment from any adverse effect caused by deposition of air pollutants - in other words, to stop the harmful effects of acid rain. That is quite simply what the public has come to expect: a quick-fix to the acid rain problem, at minimal cost.

What will S. 768 achieve?

Although the bill seeks to address the acid rain and interstate pollution problems, it does not provide a rational solution to either. It is rather a bill to reduce sulfur dioxide emissions from large utility boilers, mainly in a few midwestern states. The bill fails to reduce sulfur emissions from other sources, fails to reduce nitrogen emissions from any sources, and fails to reduce any emissions at all in nineteen states. The resulting effect will be, at best, a discouragingly small improvement in the problem. Golomb[1] at the Massachusetts Institute of Technology calculated that a 100% reduction in power plant sulfur dioxide emissions in the U.S. would ideally result in an improvement of the average pH of eastern rainfall from 4.2 to 4.4. A 10-million ton sulfur dioxide reduction might result in an average pH of 4.3 - or about a 20% reduction in acidity. This then is not a solution, but a modest first step.

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[1] D. Golomb, Acid Deposition-Precursor Emission Relationship in the Northeastern U.S.A. The Effectiveness of Regional Emission Reduction, Atmospheric Environment, Volume 17, Number 7, (July 1983) pp. 1387-1390.

What will S. 768 cost?

The cost of implementing large sulfur dioxide emission reductions vary considerably depending on how optimistic or pessimistic one's assumptions are, but significant effects can be expected in the form of increased electricity rates and disruption of traditional coal markets (and subsequent disruption of regional economies in certain coal-mining areas). Using Kentucky as an example, S. 768 would require the state to reduce sulfur dioxide emissions by about 70% below 1980 levels. A significant additional reduction would be required to offset the emission sources (power plants) that have been built since 1980. The impacts of similar reductions have been estimated for the Senate Committee Bill of 1982 (S. 3041).[2] The annual costs for Kentucky varied from 376 to 700 million dollars depending on whether fuel switching or retrofit flue gas desulfurization was adopted as a control strategy. The corresponding increase in electricity rates was 17 to 32%.

Since fuel switching does appear to be the cheaper alternative (at least for the short-run), it was assumed that most states would use this strategy to reduce emissions. Over

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[2] H.G. Enoch, "Economic Impacts of the Senate Acid Rain Bill. Some Implications for Kentucky," Kentucky Energy Cabinet, December 1982.

80% of the coal produced in Kentucky is used in other states. Fuel switching by those states could lead to loss of markets for Kentucky coal resulting in losses of 14,000 to 60,000 jobs.

- The reason for differences with previous estimates.

The dramatic impacts on the future markets for Kentucky coals, particularly the low-sulfur eastern Kentucky coals, are quite different from previous estimates by ICF Incorporated. For example, for S. 3041 ICF predicted a 20-million ton per year increase in low-sulfur eastern Kentucky coal production by 1995, which offset a predicted decrease of 2.5 million tons per year of high-sulfur coal in western Kentucky. However, the model used in those studies is based on several unsupportable assumptions. The most critical of these is that the selection of coal as a future utility and industrial fuel will not be influenced whatsoever by environmental regulations or the cost of environmental controls. The ICF model predicts a very large (and probably overoptimistic) increase in coal use by 1995 and assumes that the same amount of coal will be used regardless of whether or not there is a stringent acid rain control bill. The implication is that there is no choice but to use a certain fixed tonnage of coal in 1995. Actually, the amount of coal used is profoundly affected by the resulting electricity costs and there are other choices as the cost goes higher. Two choices of particular significance are:

- o the selection of nuclear power and electricity imports over coal-generated electricity, and

- o the selection of alternative forms of energy use (i.e., alternatives to electricity) for homes, businesses, and industry including oil, gas, and wood.

Another ICF prediction that may be challenged is the rather limited quantities of western U.S. coal moving into the eastern U.S. markets. It ignores the fact that significant markets have already been established in the east and tremendous future growth may be expected. It makes the assumption that unlimited amounts of very low-sulfur coal are available in eastern Kentucky. However, as seen in the table below, most of the market states will require a significantly lower sulfur content than is being currently supplied by eastern Kentucky.

Compliance Coal Quality Required By Utilities
Under the Mitchell Bill (S. 1706)
Assuming Fuel Switching

Market State[a]	1980 % S average of all coal delivered[b]	% S Reduction required by utilities under Mitchell bill[c]	Overall average % S of compliance coal required	1980 E. Kentucky coal delivered	
				1000 tons	% S
West Virginia	1.79	62	0.68	2,969	0.99
Alabama	1.59	54	0.73	620	1.21
Mississippi	1.64	55	0.74	725	1.11
Tennessee	2.26	73	0.61	5,115	0.96
Michigan	1.30	42	0.75	10,713	0.80
Ohio	2.49	75	0.62	11,340	0.90
Florida	2.18	47	1.16	1,892	1.58
Georgia	1.85	62	0.70	9,769	1.48
North Carolina	0.96	20	0.77	11,779	0.98
South Carolina	1.41	44	0.79	7,223	1.41
Virginia	0.88	57	0.38	1,662	1.05
Illinois	1.84	68	0.59	710	0.81

[a] Includes those states that used more than 500,000 tons of east Kentucky coal in 1980.

[b] U.S. DOE/EIA, "Cost and Quality of Fuel for Electric Utility Plants - 1980 Annual," 1981.

[c] R. M. Friedman, Office of Technology Assessment, Testimony before the Senate Committee on Environment and Public Works, October 29, 1981 (Table A-5).

The assumption of unlimited amounts of very low-sulfur coal in eastern Kentucky is a mistaken one. The amount of compliance coal at various emission limits drops off very rapidly as emission limits become more stringent. By contrast, western U.S. coal is available at the lower limit. For example, only 5% of the coal resources in eastern Kentucky can meet a 0.8 pound per million Btu standard - 81% of the coal in Montana can meet the same standard (see the following).

Percent Of Coal Resources Meeting Various
Sulfur Dioxide Emission Limits

Emission Limit (lbs of SO_2 per million Btu)	East Kentucky[a]	Montana[b]
2.0	70%	96%
1.2	43%	91%
1.0	20%	87%
0.8	5%	81%
0.6	less than 1%	73%

[a] J. C. Cobb, J. C. Currens, H. G. Enoch, Compliance Coal Resources in Kentucky, Kentucky Geological Survey, 1982.

[b] C. Stone, Compliance Coal in Kentucky and Montana, Kentucky Geological Survey, 1984.

Thus the finding here of large potential production losses for Kentucky coal appears justified in terms of three different market effects:

- o less electricity use leads to a decrease in coal's largest market,
- o increase cost of coal use leads to greater emphasis on other fuels, particularly nuclear, resulting in a

decreased share for coal in the remaining utility market, and

- of the remaining share for coal, stringent emission limits would result in low-sulfur western U.S. coal capturing a large fraction of the market.

Solving the acid rain problem.

I think EPA Administrator William Ruckelshaus made a very perceptive observation when he stated recently, "The public appears to be demanding immediate but not very painful solutions to long-standing problems that we don't know how to fix."[3] In lieu of solutions, the Congress is under pressure to pass legislation that appears "to do something." Acid rain is a long-term problem and the solution will be, must be, long-term. There are no short-term quick-fixes or "magic bullets." The Congress recognized this reality about air pollution problems in the 1970 and 1977 Clean Air Act Amendments. One of the guiding principles inferred from the Act is that clean air will result from the replacement of all our old, dirty plants and factories with efficient, clean plants using new technologies. Progress may not have been as fast as we had desired, but the solution has not changed.

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[3] W. Ruckelshaus, U.S. Environmental Protection Agency, Speech to the Detroit Economic Club, April 16, 1984.

Is the Clean Air Act working?

The perception of slow progress has led many to believe that the Clean Air Act does not work and needs overhauling. The perception may be false - it is working in Kentucky. Sulfur dioxide emissions have decreased by a third between 1976 and 1982; flue gas desulfurization (scrubber) capacity at our utilities increased from about 300 MW in 1976 to over 8,000 MW in operation or under construction today, representing an investment of over one billion dollars.[4] This progress is directly attributable to the Clean Air Act.

The development of clean technologies for coal use has been a major goal in Kentucky for over ten years. In 1974, under then-Governor Wendell Ford, Kentucky adopted a policy "to encourage and promote the development and demonstration of efficient, environmentally acceptable and commercially feasible technologies, techniques, and processes for conversion of coal into clean fuels."[5] A 55 million dollar trust fund and a 30 million dollar bonding authority were established to demonstrate new energy technologies. In addition, 47 million dollars has been spent on energy research. These are all state funds. Governor Martha Layne Collins is committed to the clean use of coal through new technologies. She strongly supports the development of fluidized bed combustion, coal cleaning, coal gasification and liquefaction. The Governor has called upon our sister states to join Kentucky in sponsoring a utility demonstration of the fluid bed process. We are moving in the right direction.

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[4] H.G. Enoch, "FGD Data Book: Utility Flue Gas Desulfurization in Kentucky, Kentucky Energy Cabinet, August, 1983.

[5] Kentucky Revised Statutes, Chapter 152 A, Department of Energy.

Is S. 768 needed now?

In view of the considerable progress made to date, perhaps the Clean Air Act does not need overhauling. Many of the recommendations for legislation have cited the prestigious National Academy of Sciences as the authority calling for immediate reductions in sulfur dioxide emissions. But this is what the National Academy of Sciences actually said on the subject: "If national policy on acid deposition is to be made on the basis of the scientific information currently available, that policy could take several forms, including maintaining the status quo. Other policies might incorporate uniform reductions (rollback) in emissions, might be designed to achieve the maximum possible environmental benefit, or might be carefully engineered to bring risks, costs, and benefits into optimal balance."[6] It should be noted that none of these possible policies suggested by the

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[6] National Research Council, National Academy of Sciences, Acid Deposition. Atmospheric Processes in Eastern North America, Washington, D.C., 1983.

National Academy of Sciences are incorporated into the "acid rain control" legislation before Congress, except for the Byrd (S. 454), Rahall (H.R. 1405), and Randolph (S.766) bills, which advocate accelerated research and mitigation measures.

Returning to their statement, the National Academy of Sciences said that policies based on current scientific information could include maintaining the status quo. A stringent interpretation of status quo could be capping sulfur and nitrogen emissions at present levels and allowing the Clean Air Act to bring about further reductions. It appears then that it is not the science that demands immediate action, it's the politics.

Is S. 768 a step in the right direction?

S. 768 would clearly accelerate the reduction of sulfur emissions over the short-run. Thus, although it may be far from a solution, it may be viewed as a step in the right direction. But is it? Consider the options.

Scrubbers - Scrubbers can reduce sulfur emissions significantly. Retrofitting new equipment on old plants is not the most efficient technical solution to emission problems. It also robs capital resources that could be used for more efficient solutions. Retrofitting scrubbers will encourage old plants to be kept on line much longer, delaying their replacement with cleaner plants. The benefit is a short-term reduction in sulfur emissions, which will come at the expense of greater long-term reductions (see Figure 1).

Fuel Switching - Fuel switching would have a similar effect. Low-sulfur fuels are not the ultimate solution to the acid rain problem, clean technology is. Clean fuels offer only very limited sulfur reductions, clean technology offers unlimited reductions. The use of clean fuels will discourage the development and commercial application of new technologies.

Fuel switching will have another undesirable side-effect known as "high grading" of coal resources. High grading results when we selectively seek out the highest quality fuels for use today, leaving behind lower quality fuels for tomorrow's users. Another effect of high grading is that lower quality coals may be spoiled in the process of obtaining high quality coal. This occurs to an extent now in eastern Kentucky. If a coal-producer can only sell coals with less than say 1.5% sulfur, he will not save the 3% or 3.5% sulfur coal that may be encountered in mining - it will become refuse. This is poor conservation of our energy resources and it will become worse when coals of 0.5% to 1% sulfur are being sought (see Figure 2). This is a phenomenon of the marketplace, operators do not mine what they cannot sell. To encourage this by legislation or regulation is to encourage wasting our national energy heritage, and there is a real cost associated with this loss. The cost will be externalized, paid for by future generations, not by the consumers of the power produced today.

What should be done to stop acid rain?

Kentucky is committed to solving the acid rain problem. We differ with our critics mainly in the nature of the solutions. I believe that there is general agreement that we need to encourage the replacement of old plants with clean, new technologies. During the interim S. 763 would achieve some modest emission reduction at great cost and at the risk of discouraging or delaying the development of new technologies.

Governor Collins would like to propose the following as an alternative to the proposed acid rain control legislation:

- Acceptance of the fact that acid rain solutions must of necessity be long-term solutions. The public should not be led to expect a painless quick-fix to this problem. Saddling one region of the country with major utility sulfur dioxide emissions reductions is not the answer. The solution will require major and expensive reductions of sulfur and nitrogen emissions in all regions of the country.
- Vigorous enforcement of the Clean Air Act. Significant achievements have already been realized due to the Act. The mechanism is in place to bring about continued progress. Some immediate reductions could be obtained through a strong enforcement effort.
- Create a climate that encourages the development and commercial application of new technology. The tech-

nical, economic, and institutional barriers to technology development need to be overcome. Incentives could be given to industries to sponsor R&D, to apply innovative technologies, and to consider early retirement of plants. The federal government could increase its support of fossil energy R&D and energy technology demonstrations. They could also support the commercial application of new energy technologies. A number of promising processes for clean coal use are essentially ready to go: among these are fluidized bed combustion, gasification combined-cycle, solvent refined coal, and H-Coal liquefaction. Economic uncertainties, the present oil glut, high interest rates and a number of other factors are delaying their application. Congress created the mechanism to speed this development in the Synthetic Fuel Corporation. Many of the goals of the Energy Security Act that formed the Corporation are consistent with the solution of the acid rain problem. The Synthetic Fuel Corporation could be an extremely potent force in the rapid advancement of environmentally acceptable energy technologies.

This concludes my prepared statement. I will be happy to answer any questions.

Figure 1

U. S. SULFUR DIOXIDE EMISSION PROJECTIONS

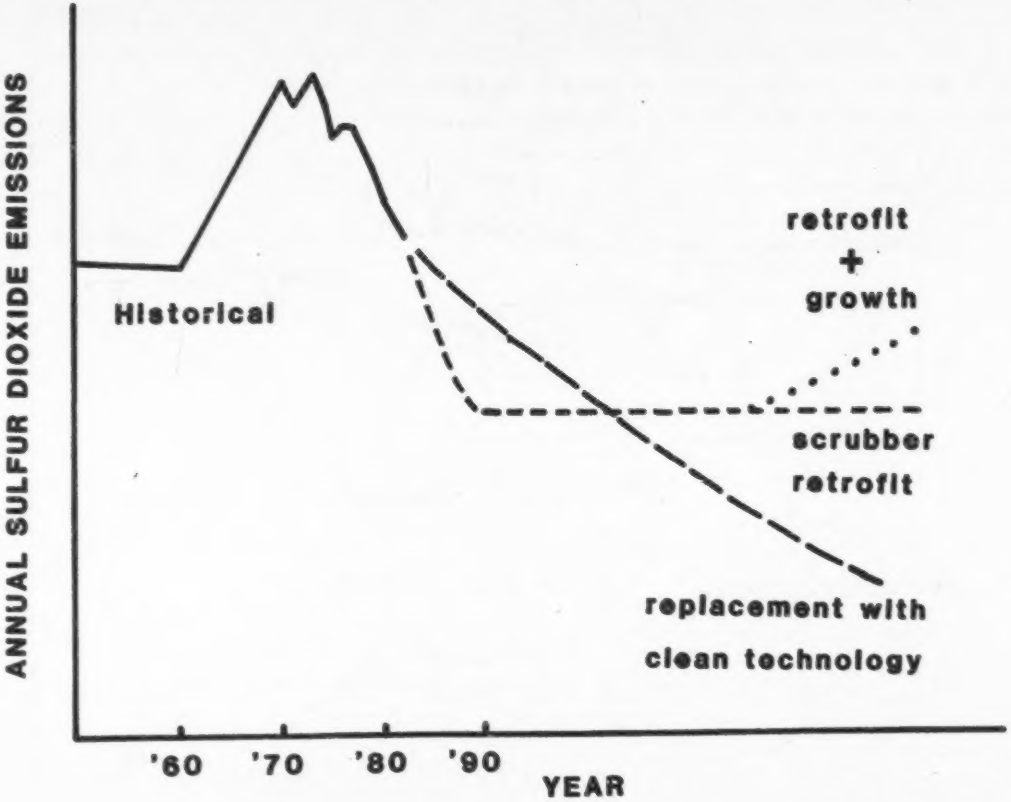
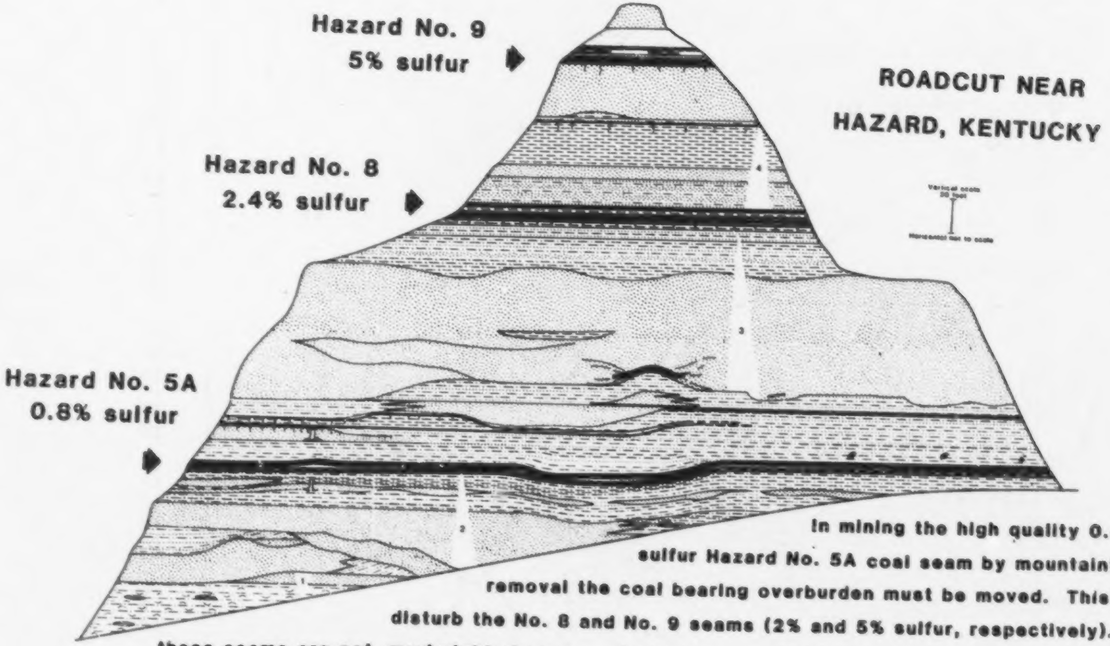


Figure 2



ROADCUT NEAR HAZARD, KENTUCKY

Hazard No. 9
5% sulfur
Hazard No. 8
2.4% sulfur
Hazard No. 5A
0.8% sulfur
Vertical scale
20 feet
Horizontal not to scale

In mining the high quality 0.8% sulfur Hazard No. 5A coal seam by mountaintop removal the coal bearing overburden must be moved. This will disturb the No. 8 and No. 9 seams (2% and 5% sulfur, respectively). If these seams are not marketable because of sulfur content they may be spoiled in the process of mining the No. 5A.

Senator WARNER. What would be your estimate of the job loss in the Kentucky mining industry if the Senate and, eventually the Congress would adopt S. 768 and it were signed into law?

Dr. ENOCH. We estimated a range for that job loss between 7,000 and 30,000 coal mining jobs.

Now, we did something different. We estimated that there could be jobs lost in east Kentucky, and, thereby, our estimate differs from some others that have been made who predict great gains in east Kentucky if acid rain control legislation is passed.

Senator WARNER. Well, we are fortunate to have on this committee your former Governor, now Senator Ford. He is continuously concerned about the prospects of the heavy unemployment that could result from legislation of this nature, particularly at a time when we're not certain of the direct linkage.

The Ad Hoc Committee to review the National Acid Precipitation Assessment Program filed its report in December of 1983. The report included this recommendation, and I now quote:

> The Federal funding level for development and demonstration of new control technology should be increased substantially to complement ongoing industry commitments. Development of new and improved retrofitable emission control technologies, followed by a successful pilot and demonstration scale testing, is of key importance in the potential long-term mitigation of acid deposition.

Would you agree with that?

Dr. ENOCH. I 100 percent concur. I believe therein lies the solution.

Senator WARNER. Thank you very much, gentlemen.

The Chair will now proceed to panel 6; noting that all the panel 5 witnesses are from Washington, DC; and panel 6 has witnesses from out of the Nation's Capital. In order to accommodate their travel plans, we will now hear from panel 6.

Leading off is John Jarvis, national legislative representative, United Mine Workers; Gov. John Dalton of McGuire, Woods & Battle, Richmond, VA, on behalf of the United Coal Co.; John Quarles, chairman, National Environmental Development Association; Edward Haase, Land Use and Reclamation Coordinator, Phelps Dodge Corp.

Governor Dalton, it's a particular pleasure for me to welcome you today.

Mr. DALTON. Thank you, Senator Warner. I'm delighted to be here with you.

Senator WARNER. Well, you bring to the Senate a depth of background which is very valuable in trying to make an assessment and a fair understanding of this serious question that faces the Nation.

We're delighted that you have taken the time to join us today. Thank you.

Governor, you may proceed.

STATEMENT OF HON. JOHN N. DALTON, ON BEHALF OF THE UNITED COAL CO.

Mr. DALTON. Senator Warner, for the purpose of the record, I might say that I was Lieutenant Governor of Virginia from 1974 to 1978, and Governor of Virginia from 1978 to 1982, and at the present time I'm a partner in the Richmond based law firm of McGuire, Woods & Battle.

I'm here on behalf of my client United Coal Co., which is the third largest coal producer in the Commonwealth of Virginia.

This company has divisions mining coal in West Virginia, Kentucky, and Oklahoma, as well as in Virginia. And through their subsidiary, the Dal-Tex Coal Corp., this is a member of the Alliance for Clean Energy, as is the Virginia Coal Association, which is made up of some 11 coal companies in Virginia, producing some 80 percent of the total coal production in the Commonwealth of Virginia.

You are going to hear today from the Alliance for Clean Energy, and I want you to know that my client fully endorses the remarks that will be made by the representative from ACE.

So I will confine my comments to the perspective of the producer of low-sulfur coal located in the Eastern United States.

During most of the time that I was Governor of Virginia, Virginia was the sixth largest coal producer in the Nation. In 1983, we fell to seventh in the Nation. And, based on the first quarter of 1984 figures, it appears that we will probably be down to eighth in the Nation in 1984.

I point this out simply to point out that most of the coal that is minable in Virginia is low-sulfur coal. So consequently, Virginia, a low-sulfur, eastern producer, is losing percentage to other States even though we are a low-sulfur State.

As a matter of fact, in the first quarter of 1984, it appears that Virginia, as a percent of the United States, has declined some 2.3 percent in production.

I come to you today to offer no judgment on the state of the science of acid rain, nor does my client actively support a particular piece of legislation. But I would like to say that should your committee and the full Congress determine that the Clean Air Act needs amending, and that specific acid rain legislation is required, I would urge you to keep in mind two particular points: First, that any legislation enacted to control acid rain should encompass the most cost-effective methods to achieve the mandated goal; and, second, that Virginia, and a substantial segment of the coal-producing States immediately adjacent to Virginia today produce low-sulfur coal.

It's my understanding that there are two concepts that are before the Congress. One would require scrubbers on the older powerplants, and one would be the so-called least-cost alternative, or freedom of choice approach embodied in S. 768 and the bill sponsored by Congressmen Udall and Chaney.

We feel at United Coal Co. that the least-cost alternative approach is preferable for several reasons. First, it's much less expensive to follow this approach than it is to go to scrubbers; and, second, legislation requiring scrubbers would certainly call for some kind of express or hidden tax to pay for the scrubbers. And we feel that requiring States like Virginia, which principally produce low-sulfur coal, to help subsidize a cure for a problem that may be caused by the use of high-sulfur coal would be disadvantageous for the people of our State.

I would also commend your reading the August 12, 1983, editorial from the Washington Post entitled "Clean Air Cost," and also the article accompanying that in that same newspaper that day which was written by Paul R. Portney, a senior fellow at Resources for the Future. I have filed a copy of that with my statement, and I would hope that all of that would be included in the record.

Senator **Warner**. Without objection.

Mr. **Dalton**. That editorial does wind up by saying—and I quote, "The rule for EPA to propose, and Congress to adopt, is a sharp reduction in powerplants' emissions, but one that leaves it up to each company to figure out the best and most efficient way to achieve it."

Mr. Chairman, this should not be viewed as an East-against-West proposition.

The current economically recoverable low-sulfur reserves in the Eastern States of the United States amount to some 7.6 billion tons, and 8.0 tons in the West.

And, as a matter of fact, the Dal-Tex Coal Co., that is a subsidiary of United that I mentioned was a part of ACE, has some 400 million tons of compliance or conforming coal which is mined by United Mine Workers and is being sold daily in the Eastern United States.

Should your committee and the full Senate and the House of Representatives determine that legislation is necessary to combat the acid rain problem, I hope that, first, you will conclude that the least-cost alternative, or freedom of choice mode is preferable; and, second, that this approach has the support of, and will favorably impact on Virginia and our bordering coal-producing States.

I appreciate the opportunity to be with you this afternoon, Senator Warner, and I look forward to seeing you tonight. I believe we're going to be at the same place tonight.

[The prepared statement of Mr. Dalton follows:]

TESTIMONY OF
JOHN N. DALTON
ON BEHALF OF UNITED COAL COMPANY
BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
U.S. SENATE
APRIL 30, 1984

Mr. Chairman, Members of the Committee, I am John N. Dalton, Partner in the Richmond, Virginia, law firm of McGuire, Woods & Battle. I am appearing today on behalf of United Coal Company. United Coal Company is the third largest producer of coal in Virginia. It has divisions doing business in West Virginia, Kentucky and Oklahoma.

United Coal Company through its Dal-Tex Coal Corporation subsidiary is a member of the Alliance for Clean Energy as is the Virginia Coal Association, a trade association, made up of 11 coal producers in Virginia. They account for 80% of coal production in the State.

Mr. Chairman, inasmuch as the committee will hear today from The Alliance for Clean Energy and because my client fully endorses those remarks, I shall confine my comments to the perspective of the producer of low sulfur coal from east of the Mississippi River, particularly southwestern Virginia and southern West Virginia.

Two of the biggest issues I faced as Governor of Virginia from 1978 until 1982 were helping to expand the market of Virginia coal and keeping the cost of electricity as low as practicable under our State's regulatory scheme.

According to the Virginia Center for Coal and Energy Research, Virginia ranked sixth among states as a coal producer during three of the last four years I held office.

In 1983, Virginia slipped to seventh and the best estimate for 1984 is that our State will drop another place to eighth.

Likewise, year to date coal production figures for the twelve week period ending March 24, 1984[1] show that while the United States as a whole has increased production 14.6 percent, Virginia as a percent of the United States has declined 2.3 percent. In fact, Virginia as a percent of Central Appalachian has declined 7.3 percent.

When I took office in January, 1978, the average yearly residential rate payer's bill was $42.64 per 1000 kilowatt hours. Today that same bill is $67.33. You can see that the pressures to recapture costs have been great.

Mr. Chairman, I come before you today to offer no judgment on the state of the science of acid rain nor does my client actively support a particular piece of legislation. I recognize that the Congress and the agencies that you have charged with the task must make recommendations based on all empirical data. My purpose - and that of the United Coal Company - is simple:

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[1] Based on millions short tons.

Should your committee and the full Congress determine that the Clean Air Act needs amending and that specific acid rain legislation is required, I urge you to keep in mind these two points. First, that any legislation enacted to control acid rain should encompass the most cost effective methods to achieve the mandated goal. Second, that Virginia and a substantial segment of the coal producing states surrounding Virginia, including southern West Virginia and Kentucky, today produce low sulfur coal.

Let me briefly discuss both points.

It is my understanding that there are primarily two legislative concepts being considered to reduce emissions of sulfur dioxide. The first is the forced scrubbing approach embodied in Congressmen Waxman's and Sikorski's bill. The second is the so called least-cost alternative or freedom of choice legislation embodied in S768 and in a similar bill on the House side introduced by Congressmen Udall and Chaney .

It is important to note that the proponents of both concepts agree that the environmental effects of both are identical. Thus, the analysis is which of these methods meets those environmental goals in a manner that does the least harm to affected industries and the taxpayer, or the electric rate payer.

I believe that the freedom of choice or least-cost alternative approach is preferable for several reasons.

First, in most cases electric utilities will be able to achieve sulfur reductions much less expensively by converting to low sulfur coal rather than investing in and utilizing scrubbers.

Second, legislation requiring scrubbers will certainly require some sort of express or hidden tax to pay for those scrubbers. It is my view that this tax would unfairly penalize the states which do not burn high sulfur coal. In addition, it would add insult to injury by requiring states like Virginia which produce low sulfur coal to help subsidize a cure to a problem probably caused by the use of high sulfur coal.

The freedom of choice proposal represents a sensible alternative to the high cost of scrubbers. The least-cost alternative approach would allow us to solve the acid rain problem faster, at less cost and without penalizing the states who aren't the main cause of the problem.

I commend to your reading the Friday, August 12, 1983, Washington Post editorial entitled "Clean Air Cost." The editorial points out that the least-cost alternative method is preferable. The editorial refers with favor to an op-ed article on the same page by Paul R. Portney, a senior fellow at Resources for the Future. Mr. Chairman, I have attached a copy of that editorial and article to my statement and ask that it be made part of the record. However, I would like to read the closing sentence: "The rule for EPA to propose, and Congress to adopt, is a sharp reduction in power plants' emissions - but one that leaves it up to each company to figure out the best and most efficient way to achieve it." [Emphasis Added]

If an electric company can - at a lower cost than by installing scrubbers - reduce sulfur dioxide levels to a level accepted by Congress by switching to low sulfur coal, doesn't it make sense to permit such freedom of choice?

The second and final point I wish to make is this: It is totally incorrect to view the least-cost alternative approach versus the mandatory scrubber approach as a battle of East versus West.

There are vast quantities of abundant and inexpensive low sulfur coal in the East as well as in the West. This coal can be used to substantially reduce sulfur emissions.

The following statistics, I believe, should quiet any argument that the low sulfur approach would benefit only the Western states.

Current economically recoverable low sulfur coal reserves amount to 7.6 billion tons in the East and 8.0 billion tons in the West for a total of over 15 billion tons. The United States Department of Interior's estimate of in place low sulfur reserves is even higher at a total of 193.8 billion tons with 26.5 billion tons in the East.[2] My client alone has great reserves. Dal Tex, a subsidiary of United Coal, has 400 million tons of compliance or conforming coal which is mined by United Mine

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[2] See Feb. 9, 1984, Testimony of William T. McCormick, Jr. Before Committee on Environment and Public Works, U.S. Senate.

Workers members and sold on a daily bais into the marketplace as environmentally accepted coal.

CONCLUSION

Mr. Chairman, acid rain control legislation will undoubtedly impact on many facets of life in the United States.

Certainly, it will have a significant effect on the environment, but it will also effect energy and the cost of energy.

Likewise, the path Congress chooses to follow and the choice it makes in the method to deal with the acid rain problem can profoundly effect Virginia and the many coal companies in and around our State, including the United Coal Company.

Coal is clearly becoming the fuel of choice for more and more of our electric utilities. Its attractive cost and its uncontroversial nature have the potential to further reduce our country's dependence on foreign oil. I would hope that Congress would give a high priority to increasing the use of coal.

Should your Committee and the full Senate and the House of Representatives determine that legislation is necessary to combat the acid rain problem, I hope that, first, you will conclude that the least-cost alternative freedom of choice mode is preferable, and that secondly, this approach has the support of and will favorably impact on Virginia and our bordering coal producing states.

Why would we wish to put miners of low sulfur out of work when there is plenty of work for them to do mining low sulfur coal.

Freedom of choice is synonymous with competition and free enterprise and Mr. Chairman, on behalf of my client, United Coal Company, I ask that you give it and other low sulfur producing companies from both the East and West a chance to compete.

The Washington Post

Friday, August 12, 1983

Clean Air Costs

THE REAGAN administration is now working out its plans for reducing acid rainfall, and they are inevitably going to be expensive. The Environmental Protection Agency is about to make the basic decisions on the program that it will send to the White House next month. Cost estimates for an adequate cleanup range upward from several billion dollars a year. It won't be tax money. It will, quite properly, be added to people's electric power bills. But which people, and how much?

Perversely, it is the most expensive program that is most attractive in political terms. That's because it would protect the jobs of some miners—at a heavy cost in unnecessary mechanical equipment. Paul Portney examines the economics of that choice in an article on the opposite page. Unfortunately, if Congress follows precedent, it will adopt this most costly of solutions.

When Congress revised the Clean Air Act in 1977, it wanted to limit the air pollution generated by future power plants. The best and cheapest way to get cleaner air would have been simply to limit the pollution from each plant. Most coal-fired plants would have complied by switching to low-sulfur coal. The largest deposits of low-sulfur coal are in the West. Most eastern and midwestern coal has a high sulfur content, and it is this sulfur that causes acidity in rain. A simple and efficient limit on air pollution would have cut sales of the eastern mines in favor of their western competitors. Not incidentally, most eastern miners belong to the union, and most western miners do not.

Instead of imposing the most efficient remedy, Congress in 1977 chose instead a bizarre alternative —to require every new plant, whether it burned high- or low-sulfur coal, and whether its exhaust gases were clean or dirty, to install the "best available control technology"—that is, stack scrubbers. Scrubbers are very expensive devices. The requirement was pushed through Congress by an alliance of eastern mines, unions and environmental lobbyists.

The result was a reduction in air pollution but, as continued acidity in rain demonstrates, not enough of a reduction. The next step is to tighten the requirements on the pre-1977 generating plants. The question now is precisely the same as in 1977. Should Congress simply set lower pollution limits, or should it again try at the same time to protect eastern mines and miners? As Mr. Portney points out, the number of jobs at stake is small, while the costs are extremely high.

Should consumers' electricity bills be raised to distort the coal business in favor of eastern mines? Put that way, the question answers itself. The rule for EPA to propose, and Congress to adopt, is a sharp reduction in power plants' emissions—but one that leaves it up to each company to figure out the best and most efficient way to achieve it.

Paul R. Portney

High-Price Cure for Acid Rain

The federal government has a choice between two strategies to reduce the damage done by acid rain. One would cost a great deal more than the other. Congress seems to be moving toward the more expensive method, on grounds that it will save jobs in eastern and midwestern coal mines. But the price of protecting those jobs would be high, and the number of jobs at stake is small.

The case for prompt legislation to diminish acid rain appears increasingly strong.

The National Academy of Sciences and the administration's own Interagency Task Force on Acid Precipitation have pointed in recent reports to the apparent seriousness of the acid rain problem and to its likely causes. Congress now seems ready to reject the "do more research and pray" approach and pass a bill to force utilities to cut back emissions of the sulfur and nitrogen oxides that are thought to be the precursors of acid rain. Fixing attention on existing coal-fired electric power plants (which account for 65 percent of sulfur dioxide emissions in the United States), there are two ways to achieve the large reductions needed. These plants could install mechanical devices known as scrubbers which filter out the sulfur dioxide released when coal is burned in the boilers. (All new power plants built in the United States already face this requirement.) Or they could shift to coal with a lower initial sulfur content and thus address the problem at an earlier stage.

Neither approach is cheap. A scrubber would account for about $200 million of the $1 billion or so it takes to build a new 1,000-megawatt power plant. Retrofitting the very large, older plants built before scrubbers came along can be even more expensive. On the other side, low-sulfur coal, because of its environmental advantages and because some of it must be shipped from western mines to the East and Midwest, can be expensive. In fact, depending on its location, a power plant might have to spend an additional $15 a ton for low-sulfur coal, not a trivial sum to a plant burning several million tons a year.

But while the two means of sulfur removal are expensive, they are not equally so. If forced to reduce sulfur dioxide emissions by a fixed amount, some power plants would voluntarily choose scrubbers. But the overwhelming majority would find it more economical to shift to lower-sulfur coal.

One would think, then, that this presents no problem to those designing a plan to control acid rain. The plan should involve only three simple steps. First, decide the total amount by which annual sulfur dioxide emissions should be reduced. Second, apportion the desired reduction among existing plants. Finally, let each plant decide for itself how best to achieve its share of the cutback, allowing each to trade emission reductions with others as under EPA's current offset policy. Since each plant would choose the least expensive alternative, the total costs of the sulfur reduction program would be minimized. This "least-cost" approach would be good regulatory policy by either Republican or Democratic lights.

But not so fast. Take a look at H.R. 3400, introduced by Reps. Gerry Sikorski (D-Minn.) and Henry Waxman (D-Calif.), now destined to be the leading candidate among the competing acid rain bills Congress is considering. It would take an unfortunate step beyond the approach suggested above and force the 50 "dirtiest" power plants in the country to install scrubbers to meet their cutbacks even though most would prefer to go the low-sulfur coal route.

Forcing the installation of scrubbers would be about $1.6 billion per year more expensive than allowing these plants to choose for themselves, *and it would produce no additional environmental benefits.* These added costs would be borne by households all across the country, because another section of the Sikorski-Waxman bill would impose a tax on the generation of all non-nuclear electricity in the United States to help subsidize the installation of the scrubbers. (Why it would not be levied directly on the emission of sulfur dioxide is a mystery—it is that, not electricity, which causes acid rain.)

Why should the United States spend $1.6 billion more than necessary to guard against acid rain? Several justifications now floating around are too weak to bear repeating. There is, however, one very legitimate concern—the job losses that might result among the miners of high-sulfur coal if existing power plants are allowed to use low-sulfur coal instead of scrubbers as part of an acid rain control plan.

Even among those used to the boom-and-bust nature of coal mining, involuntary unemployment can be a bitter pill to swallow. But many of the miners would be re-employed in the same or nearby areas, since low- and high-sulfur coal are often found close together. In Appalachia alone, for instance, many more mining jobs would be created than would be lost. At most, net job losses in the eastern United States under the least-cost approach would amount to about 2,000.

Since H.R. 3400 would cost $1.6 billion more than the least-cost approach, it would soon be forcing Americans to spend $800,000 a year for each mining job it saved, roughly 30 times what each of these miners could be expected to earn in a year. This sort of foolishness begs for a better solution — and one is at hand. Why not simply use some of the considerable savings possible under the least-cost approach to retrain or help relocate any miners and their families?

In fact, a scheme to compensate the unemployed could be created—one like the assistance given to loggers who lost their jobs when the Redwood National Park was expanded. Under such a plan, miners involuntarily unemployed might receive their full pay for a period of five years or so with the payments gradually being reduced as new employment opportunities present themselves.

There is a good reason for Congress to be concerned about both acid rain and job losses. But the attempt to address both in H.R. 3400 does a disservice to environmental policy and employment policy alike.

The writer is a senior fellow at Resources for the Future.

Senator **Warner**. Thank you. That indeed will be a privilege.

Governor, the previous panel in response to a question submitted by Senator Ford, the witness gave an estimate of the jobs that would be lost should S. 768 become law.

Based on your extensive experience as Lieutenant Governor and Governor, could you provide any comparable figures for Virginia; and, if not, submit them for the record at a future point in time?

Mr. **Dalton**. Senator Warner, I do not have comparable figures to give to you, but I feel relatively certain that if we had the freedom of choice approach that the Virginia coal employment would improve.

Senator **Warner**. Thank you very much, Governor.

We will now turn to Mr. Jarvis, national legislative representative, United Mine Workers.

STATEMENT OF JOHN T. JARVIS, NATIONAL LEGISLATIVE REPRESENTATIVE, INTERNATIONAL UNION, UNITED MINE WORKERS OF AMERICA

Mr. **Jarvis**. Thank you, Mr. Chairman.

Senator **Warner**. Mr. Jarvis, it's a pleasure to see you again and have you with us.

Mr. **Jarvis**. It's a pleasure to be here.

Mr. Chairman and members of the committee. My name is John Jarvis. I'm the national legislative representative of the international union, United Mine Workers of America.

On behalf of the UMWA, I would like to thank the committee for holding these very important hearings.

Mr. Chairman, if I might, I'd like to submit the formal statement for the record and just summarize.

Senator **Warner**. Without objection.

Mr. **Jarvis**. Decisions made with regard to the clean air policy are vitally important. For nearly 20 years, control of air pollution has been a major national priority. Because of the concerted national efforts, the quality of the air has improved markedly over the last decade.

To be sure improvements in air quality have involved substantial costs. But most observers agree that the trend has been good for both public health and the environment.

However, we must recognize that some of the cost, in particular the disruption of coal mining jobs and communities have been unnecessary.

We must assure these workers and their families that they will not be forced to sacrifice their livelihood as we pursue the worthy goals of the Clean Air Act.

For these reasons, the act should continue to serve as a tool to encourage and foster the development of new technologies to control air pollution.

Technology-based pollution control strategies protect current jobs and provide new ones.

Secure employment always is a priority for those of us who represent workers. Today, however, that concern looms ever larger.

Unemployment already has taken a severe toll on the coal miners and coalfield communities. Data from the Mine Safety and

Health Administration indicate that there were about 60,000 fewer people working in the bituminous coal industry in the first half of 1983, as compared to the average 1982 unemployment.

This already grave situation in the coal mining communities would be aggravated by acid rain control legislation.

The magnitude of the job losses associated with acid rain controls has depended on the utilities industries' response to mandated reductions. The industry has several options by which it can fulfill the requirements of reducing sulfur dioxide emissions at existing generating units.

Utility companies could retrofit the units with scrubbers, retire older units and replace them with less-polluting new ones, wash or blend coal supply to decrease sulfur content, or switch from high-sulfur coal to low-sulfur coal.

The degree of fuel switching that occurs as utilities attempt to reduce emissions will determine the extent of unemployment that would result from acid rain control legislation.

Some proponents of acid rain legislation actually have touted fuel switching as a low-cost means of addressing the acid rain issue. But an examination of the job losses inherent in fuel switching clearly shows the solution to be an economic disaster.

U.S. Department of Energy has projected that between 50 and 75 percent of the emissions reductions would be achieved by fuel-switching if a bill similar to the 1982 Senate Environment and Public Works Committee bill, or that recently adopted by this same committee, became law.

A UMWA analysis of the acid rain employment impacts showed that if 50 percent of the reductions were achieved by fuel-switching, over 39,000 high-sulfur coal miners' jobs would be lost.

Under the 75-percent projection, nearly 60,000 coal miners could face the unemployment line.

Of course, these direct job losses would lead to indirect job losses in support and service industries.

Assuming a conservative 2.25-jobs-multiplier, between 87,000 and 134,000 additional jobs could be lost due to the utilities' actions.

With that in mind, Senator, I'd just like to add, acid rain is a complete and too often divisive issue that cuts across many disciplines and interest.

Science has continued to argue causes and cures. Economists argue cost and benefits. Politicians argue equity and feasibility. Questions about the nature of this phenomenon will continue for many years.

Despite the questions, however, there is considerable political pressure to do something. If society as a whole, through its elected officials, determines to take actions to control acid rain, then the action must be equitable.

The UMW submits that there is no equity in solutions that result in the loss of thousands of jobs and the economic destruction of hundreds of communities.

Thank you for your time.

[The prepared statement of Mr. Jarvis follows:]

STATEMENT OF JOHN T. JARVIS

NATIONAL LEGISLATIVE REPRESENTATIVE, INTERNATIONAL UNION

UNITED MINE WORKERS OF AMERICA

BEFORE THE

COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

Washington, D.C.

April 30, 1984

Mr. Chairman and members of the Committee. My name is John Jarvis. I am the National Legislative Representative of the International Union, United Mine Workers of America.

On behalf of the UMWA I would like to thank the Committee for holding these very important hearings.

The United Mine Workers of America is composed of approximately one-quarter million working, retired and unemployed coal miners throughout the United States and Canada. While our membership is heaviest in the coal-mining communities east of the Mississippi River, we represent thousands of underground and surface coal miners in western states, including Arkansas, Oklahoma, Kansas, Missouri, Arizona, New Mexico, Colorado, Utah, Wyoming, Montana, and North Dakota. All told, we represent approximately 70 percent of the workers in the U.S. coal industry.

Mr. Chairman, coal has provided the energy for America's social and industrial progress. Throughout the first half of the century coal and coal miners provided the backbone of American industrial might. Coal provided heat and electricity to homes, businesses and factories and powered transcontinental railroads and transoceanic ships.

In the last thirty years, however, coal has been subordinated to petroleum and natural gas as an energy source, and substantial federal resources have been allocated to the development of nuclear power. The UMWA believes that the energy policies of the last thirty years have weakened our economy and threatened our national security. To regain energy independence and economic strength, the U.S. must adopt energy and economic policies that rest squarely on coal.

Formulating an energy policy with coal as its centerpiece requires a comprehensive review of the coal cycle from production to end use. The various elements cannot be viewed in isolation; major problems in transportation, production, consumption, or in regulatory or tax policy can impede the development and growth of the coal industry. Coherent policies can allow us to achieve our goal of energy security, help revitalize our industrial heartland and create jobs in all sectors of the economy.

That is why decisions made with regard to national clean air policy are vitally important. For nearly twenty years, control of air pollution has been a major national priority. Because of concerted national efforts, the quality of the air has improved markedly over the last decade. To be sure, improvements in air quality have involved substantial costs, but most observers agree that the trend has been good for both public health and the environment. However, we must recognize that some of the costs -- in particular the disruption of coal mining jobs and communities -- have been unnecessary. We must assure these workers and their families that they will not be forced to sacrifice their livelihood as we pursue the worthy goals of the Clean Air Act.

For these reasons, the Act should continue to serve as a tool to encourage and foster the development of new technologies to control air pollution. Technology-based pollution control strategies protect current jobs and provide new ones. One such strategy is embodied in the "percentage reduction" provision of the 1977 Clean Air Act Amendments, which requires all new power plants built in the United States to apply technology to reduce emissions. In this way, traditional regional coal markets and employment are protected. In addition, percentage reduction allows all of our coal resources throughout the nation to be burned in power plants while still meeting the national ambient air quality standards that protect public health. This provision is a good example of public policy that is both economically and environmentally beneficial. It allows us to use our vast coal resources while moving toward energy independence. The concept of "percentage reduction" will save thousands of jobs and will allow our nation's industrial base to continue to use relatively inexpensive local coal while moving toward cleaner air.

Secure employment always is a priority for those of us who represent workers. Today, however, that concern looms ever larger. Unemployment already has taken a severe toll on coal miners and coal field communities. Data from the Mine Safety and Health Administration indicate that there were about 60,000 fewer people working in the bituminous coal industry in the first half of 1983, as compared to the average 1982 employment. These staggering numbers translate to an industry-wide unemployment rate of about 30 percent. This already grave situation in the coal mining communities would be exacerbated by acid rain control legislation. The magnitude of job losses associated with acid rain controls is dependent on the utility industry's response to mandated reductions. The industry has several options by which it can fulfill the requirement of reducing sulfur dioxide emissions at existing generating units. Utility companies could retrofit the units with scrubbers, retire older units and replace them with less polluting ones, wash or blend their coal supplies to decrease sulfur content or switch from high-sulfur coal to lower-sulfur coal.

The degree of fuel switching that occurs as utilities attempt to reduce emissions will determine the extent of unemployment that will result from acid rain control legislation. Some proponents of acid rain legislation actually have touted fuel switching as a low-cost means of addressing the acid rain issue, but an examination of the job losses inherent in fuel switching clearly shows this solution to be an economic disaster.

The US Department of Energy has projected that between 50 and 75 percent of the emissions reductions would be achieved by fuel switching, if a bill similar to the 1982 Senate Environment and Public Works Committee bill or that recently adopted by this same Committee, became law. A UMWA analysis of acid rain employment impacts showed that if 50 percent of the reductions were achieved by fuel switching, over 39,000 high-sulfur coal miners would lose their jobs.

Under the 75 percent projection nearly 60,000 coal miners could face the unemployment line. Of course, these direct job losses would lead to indirect job losses in support and service industries.

Assuming a conservative 2.25 jobs multiplier, between 87,000 and 134,000 additional jobs could be lost due to the utilities' actions. Other analyses support these conclusions. As an example, the Congressional Research Service analyzed job losses in six states that are most affected by coal market shifts due to acid rain. These states include Illinois, Indiana, Kentucky, Ohio, Pennsylvania and West Virginia. CRS concluded that the direct coal mining job losses would range from 21,950 to 32,850 in those six states. With the addition of the indirect job losses that would occur, CRS concluded that between 71,338 and 106,762 people could lose their jobs in these areas. (see Attachment I).

The Energy Information Administration has published a report analyzing the market impact of acid rain controls. EIA made specific projections on coal tonnage that would be lost in four states, Illinois, Indiana, Pennsylvania and Ohio.

Using EIA's projections we calculated employment impacts based on 1982 average productivity in those states. The combined analysis showed the following: Illinois would lose 37 million tons of production by 1995, representing approximately 60 percent of total 1982 production. This would result in the loss of 11,932 coal industry jobs in Illinois. Using again the 2.25 indirect jobs multiplier, the total job loss in Illinois would be 38,779.

Indiana is projected by EIA to lose 14 million tons of coal representing about 47 percent of 1982 production. This would mean a direct job loss of 3,016 coal mining industry jobs, while the total job loss would be 9,802. Pennsylvania is estimated to lose 20 million tons representing 27 percent of 1982 production. Coal mining job losses would reach 7,874, and total job losses for Pennsylvania would be 25,590. EIA projected Ohio to lose 16 million tons or 44 percent of 1982 production. The coal mining industry in Ohio would lose 5,694 jobs while, overall, Ohio would lose 18,505 jobs.

Because these drastic economic consequences clearly are unacceptable, Congressmans Sirkorski and Waxman have introduced a bill that attempts to deal with acid rain while avoiding wholesale job disruption. I believe that this is the first emissions reduction bill that has been introduced that seeks to protect jobs. As a representative of coal miners, I appreciate the sincere effort that has been made by them.

We fear, however, that H.R. 3400 also will lead to the loss of coal mining jobs even though its expressed purpose is to prevent this occurrence. These job losses could occur in two ways: First, there is a potential, perhaps even a likelihood, that a significant amount of fuel switching will occur as utilities attempt to meet the three million ton residual sulfur dioxide reduction contemplated in the bill. Second, we believe that the age of some of the targetted "top fifty" utility plants will encourage the companies to retire some of the units instead of retrofitting them with scrubbers.

With regard to the additional three million ton reduction requirement, we have examined potential job losses in the coal industry if fuel switching occurs. Our analysis shows that over 13,600 coal miners could lose their jobs in six coal producing states if 50 percent of the three million ton reduction was achieved by fuel switching. For purposes of comparison, we reviewed tonnage disruption estimates for the same areas that were calculated by OTA and Peabody Coal Company. Applying the same methodology to these estimates, we calculated coal miner job displacement. OTA's tonnage displacement results in slightly more than 9,700 losing their jobs while Peabody's estimate for those six states shows nearly 15,300 coal miners would lose their jobs. The total number of jobs displaced, of course, would be much higher. The combined direct and indirect job displacement is shown in Attachment II.

In addition to these potential job losses, we are concerned that the age of many of the power plants that would be targetted for scrubbers under H.R. 3400 will lead the utility companies to retire them early rather than apply scrubber technology. A review of specific utility in-service dates shows that nearly half of the units would be thirty years old by 1990, the date for compliance. In terms of unemployment, a plant that is shut down is just as devastating to coal miners as one that switches its fuel supply.

The UMWA believes that the magnitude of job losses described herein is unacceptable, particularly in light of the current lack of scientific consensus on the issue. That is why the UMWA strongly supports legislation, which has been introduced in both the U.S. House of Representatives and the Senate, to accelerate the ongoing study of the causes and effects of acid rain. We must have more data before control legislation is enacted. Legislation that would disrupt the economies of major coal producing regions, lead to unnecessary increases in oil and gas use, seriously hamper the coal export trade, and lead to increased unemployment among coal miners simply cannot be justified at present.

However, this does not mean that we cannot begin immediately to treat those lakes found to contain high levels of acidity. According to the Environmental Protection Agency, studies have shown that treating the affected lakes with limestone or soda ash can have very beneficial effects on plants and fish life in the affected areas. The cost of such a program has been estimated to be $19 million if all the known acidified and threatened bodies of water were treated. The UMWA sincerely believes that the issue of acid rain must be met head on, but it must be done on the basis of solid scientific evidence.

Acid rain is a complex and too often divisive issue that cuts across many disciplines and interests. Scientists continue to argue causes and cures. Economists argue costs and benefits. Politicians argue equity and feasibility. Questions about the nature of this phenomenon will continue for many years. Despite the questions, however, there is considerable political pressure to do something. If society as a whole, through its elected officials, determines to take action to control acid rain, then the action must be equitable. The UMWA submits that there is no equity in solutions that result in the loss of thousands of jobs and the economic destruction of hundreds of communities.

Senator **Warner**. Thank you very much.

We understand that Mr. Quarles, of the National Environmental Development Association, is en route, and we will provide him an opportunity on a subsequent panel.

We will then go to Dr. Haase, land use and reclamation coordinator, Phelps Dodge Corp.

STATEMENT OF DR. EDWARD F. HAASE, LAND USE AND RECLAMATION COORDINATOR, PHELPS DODGE CORP., PHOENIX, AZ

Dr. **Haase**. Thank you.

I'm Dr. Edward Haase. I'm land use and reclamation coordinator for Phelps Dodge Corp. in Phoenix, AZ.

I appreciate the opportunity to appear before you on behalf of the Western Regional Council's Clean Air Ad Hoc Committee.

I respectfully request that my written statement be made a part of the hearing record, and I will summarize my remarks.

Senator **Warner**. Without objection.

Dr. **Haase**. Thank you.

The Western Regional Council is a coalition of 46 companies active in the 8 Rocky Mountain States. Our membership includes businesses engaged in financial, energy, mining, transportation, manufacturing, and other enterprises.

There's a considerable scientific and political debate as to the extent of the acid deposition problem. Although there's only limited scientific documentation that directly links manmade emissions to the problem, circumstantial evidence has produced an atmosphere of political urgency to enact legislation.

In the absence of adequate scientific data, some political solutions have tended to be regionally and economically divisive, going beyond the primary environmental goal of reducing acid rain.

Such approaches could have negative economic consequences in the West and the entire Nation. We, therefore, believe that it is essential that acid rain research be vigorously pursued to provide reliable scientific data upon which to base policy.

Available scientific information does not in itself justify a major emission reduction program to control acid rain, nor does it provide sufficient guidance as to what components ought to be contained in such a program.

Let me briefly highlight the current information. The interagency task force concluded that manmade pollutants are probably the major contributors to acid deposition in the Northeast. Virtually all of the supporting evidence is circumstantial, though.

There's an approximate coincidence of a region of highest precipitation acidity with areas of greatest SO_2 and NO_x emissions.

A small percentage of lakes in the regions of northeastern North American sensitive to acid deposition have been acidified, and their biota have changed. But the extent of actual aquatic damage is not well established.

The most consistent conclusion from agricultural research has been no effects at current ambient acidity levels in the Northeastern United States.

The net result to plants appears to be an interaction from the positive effects of sulfur and nitrogen nutrition, and negative effects of acidity. But negative effects do not appear to outweigh positive effects.

Research indicates it is unlikely that acid precipitation will affect cultivated soils adversely. There's no indication that any soils have become acid because of it.

Soil acidification is a natural process in humid regions, but acid deposition at current levels is a minor contribution.

No confirmed adverse effects from acid precipitation have been documented anywhere in the 17 Western States. Here I would like to elaborate briefly.

Precipitation monitoring data indicate that acid precipitation does occur in some western metropolitan areas, but this has been largely attributed to motor vehicles.

Rainfall acidity in the West is typically between 10 and 100 times less acidic than in the Northeastern United States.

In 1980, the 31 Eastern States accounted for more than 80 percent of U.S. SO_2 emissions. Most of the electric utilities in the 17 Western States are already subject to stringent emission limitations, and they account for less than 10 percent of total U.S. utility SO_2 emissions.

Some high elevation mountain areas in the West have surface waters that could be vulnerable to acid precipitation, if it were to become as acidic as that occurring in the Northeastern United States.

However, no realistic scenario would increase western acidity to the extent experienced in the Northeastern United States.

Western arid or semiarid soils are not normally leached and they do not naturally acidify. And many can assimilate acidic deposition to an almost unlimited extent, with no foreseeable adverse effects.

Sulfur in a variety of forms and in large quantities has long been used as a soil amendment in arid and semiarid regions.

Some 10 million hectares of irrigated agricultural land in 17 Western States could benefit from the proper application of sulfur compounds.

Considering nitrogen and sulfur nutrition, it appears that there may often be a greater probability for net beneficial effects than for adverse effects from acidic deposition, if it were to occur in arid and semiarid regions.

On the Interagency Task Force, research underway and planned by that task force appears to be on a track that will provide useful information on the acid precipitation problem.

The potential for expediting research and pooling resources through interagency cooperation ought to be fully utilized.

Two extreme reactions to acid precipitation problems are to do nothing at all, or to implement a massive emission reduction program based on the supposition that need and cost effectiveness could be shown sometime in the future. To do nothing ignores the circumstantial evidence, and implicates antropogenic emissions to acid precipitation in eastern North America.

On the other hand, enacting a massive emission reduction program without responding to ongoing research and cost effectiveness could needlessly expend tens of billions of dollars and have severe regional and national economic effects.

Premature and costly regulatory action to reduce emissions without proportional beneficial results would be unwise.

Some proposed legislation would unjustifiably spread the cost to the Western States where major and costly emission reduction programs have already been implemented, and there the potential for a future acid precipitation problem is significantly less than in the East.

The results of proposed legislation that would dictate the method of emission reductions, rather than allow for flexibility by sources to choose the most cost-effective means of compliance, this would further exacerbate the already unfavorable cost effectiveness of these proposals.

Legislative action, unfortunately, may not wait for more substantial data. Therefore, we recommend that if any legislation is enacted, it should adhere to the following principles: Move ahead with research to provide the adequate scientific basis for policy decisions. In the meantime, any reductions should be phased and cost-effective based upon what we know, targeted to vulnerable areas in the east, and with increased mitigation measures as initial reductions are being achieved. Permit flexibility in achieving SO_2 reductions, and promote the most cost-effective methods available. Avoid spreading the cost, as it will drive the total cost of reductions up and penalize those who have already cleaned up.

We appreciate this opportunity to present our views on the current state of scientific knowledge on acid precipitation and are heartened that the Senate Committee on Energy and Natural Resources has focused on this topic.

Thank you.

[The prepared statement of Dr. Haase follows:]

STATEMENT OF THE WESTERN REGIONAL COUNCIL ON IMPLEMENTATION OF THE ACID PRECIPITATION ACT OF 1980

PRESENTED BY
Edward F. Haase
Before the
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES
April 30, 1984

I am Dr. Edward F. Haase, Land Use and Reclamation Coordinator for the Phelps Dodge Corporation in Phoenix, Arizona. I appear before you on behalf of the Western Regional Council's Clean Air ad hoc Committee.

The Western Regional Council is a coalition of 46 companies active in the eight Rocky Mountain States. Our membership includes businesses engaged in financial, energy, mining, transportation, manufacturing and other enterprises. We appreciate the opportunity to participate in today's hearing.

Acid deposition has been recognized as a problem in the northeastern United States and southeastern Canada. However, there is considerable scientific and political debate as to the extent of the problem -- to what extent is it a real problem -- to what extent is it a potential problem or an undetermined problem.

Despite these fundamental questions, there is strong public and political pressure for Congress to enact legislation. In the absence of adequate scientific data, political solutions have been embodied in some acid rain proposals which tend to be regionally and economically divisive. These proposals go beyond a primary environmental goal of reducing acid rain and its effects and could have negative economic consequences in the West as well as throughout the entire nation. We therefore believe it is essential that acid rain research be vigorously pursued so that reliable scientific data can be available as quickly as possible upon which to base governmental policy.

Our statement summarizes pertinent current scientific data, briefly comments on the Interagency Task Force research plan, and provides our recommendations regarding legislative proposals to address acid rain.

We believe it becomes clear in reviewing available scientific information that it does not in itself justify a major emission reduction program to control acid rain nor does it provide sufficient guidance as to what components ought to be contained in such a program. Although there is limited scientific documentation that directly links man-made emissions to the problem, circumstantial evidence has produced an atmosphere of political urgency to enact legislation. We believe that particularly under these circumstances our acid rain program recommendations are a sound approach.

We have relied primarily on two important reviews to assess the documented state of scientific knowledge on acid precipitation:

1) The 1982 Annual Report prepared by the Interagency Task Force on Acid Precipitation and
2) The two-volume, 1200 page, EPA Public Review Draft of May 1983 titled: The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Review Papers which was authored by 57 scientists, most of whom are university scientists.

THE PROBLEM IN EASTERN NORTH AMERICA - CIRCUMSTANTIAL EVIDENCE

Although the Interagency Task Force concluded that man-made pollutants are probably the major contributors to acid deposition, virtually all of the supporting evidence is circumstantial. There is an approximate coincidence of the region of highest precipitation acidity with the areas of greatest SO_2 and nitrogen oxides emissions.[1] That region is generally the vicinity of the northeastern U.S.

Even though the evidence is circumstantial, a committee of the National Academy of Sciences has concluded it is strong enough to recommend a reduction in eastern SO_2 emissions.[2] However, no one has been able to identify the specific changes in acid deposition patterns that would result from a given change in precursor emissions. Research regarding the phenomenon of long range transport and the relative contributions from local and distant sources is still inconclusive. One group of scientists reported this month "that the hypothesis of a linearly proportional relationship between SO_2 emissions and sulfate deposition, as suggested by the NAS committee, is not uniformly supported in that, to the extent such a relationship exists, it seems more likely to exist with respect to SO_2 emissions from relatively nearby sources. This conclusion provides an important qualification to the conclusions of the NAS study."[3]

AQUATIC EFFECTS

Initial surveys indicate that a small percentage of lakes in the regions of northeastern North America sensitive to acid deposition have been acidified, and their biota have changed, but the extent of actual aquatic damages is not well established.[1]

In the Adirondacks, one of the most sensitive regions in North America, the State of New York has classified 3.6% of the lake areas as critical and 14% endangered. Acid deposition appears to be a major contributor to this acidification, but the rates of change and the factors controlling it are still poorly understood.[1] It is also unclear whether acidic deposition is the main culprit since natural soil acidity in the watershed may often be a more significant source. The trends of precipitation acidity are also unclear. Over the past 25 years, the historical data, either measured or calculated, do not allow quantification of an acidity increase in eastern North America.[4]

VEGETATION EFFECTS

The most consistent conclusion from all the agricultural research to date has been no effects at current ambient acidity levels in the northeastern United States (pH 4.0-4.2).[1] Much of the reported research has resulted from simulated acid precipitation applied experimentally, usually at much higher acid concentrations than have been measured consistently in preciptiation. There is no direct evidence that acidic deposition currently limits forest growth in either North America or Europe although it is still too early to conclude that there has been no effect.[4]

It is interesting to note that the experimental application of acid precipitation to crop species has shown both positive and negative effects. Nitrogen is commonly the limiting nutrient in forest ecosystems and inputs from precipitation are likely to improve forest productivity in many cases.[4] Similarly sulfur deficient soils occur in parts of at least 11 of 31 eastern states and 9 of 17 western states based on crop responses to sulfur fertilization.[5] Thus, the net result to plants appears to be an interaction from the positive effects of sulfur and nitrogen nutrition and negative effects of acidity. Experimental research indicates that adverse effects of acidity do not outweigh the beneficial effects of nutrition although no confirmed effects on vegetation have been reported under ambient conditions attributable to rainfall acidity.[4]

SOIL EFFECTS

Research indicates it is unlikely that acid precipitation will affect cultivated soils adversely. Soils that have been amended in agricultural practice will not be harmed by acid deposition.[4] Although some non-agricultural soils in forests and grasslands of humid eastern North America may be sensitive to acidification from acid precipitation, there is no indication that the soils have become acid because of it or that forest production is being affected adversely.[1] Soil acidification is a natural process in humid regions, but acid deposition, at current levels, is a minor contribution.[4]

HEALTH EFFECTS

In a few cases, acidic water from wells and municipal reservoirs has been associated with elevated concentrations of heavy metals leached from domestic water supply pipes. A linkage to acidic deposition, if any, remains unclear.[1] No adverse health effects have been documented as a result of metal mobilization by acidic deposition.[4]

MATERIALS EFFECTS

The role played by acid precipitation on building materials is still a major unknown, especially in regard to long-range transport of air pollutants. Natural agents such as moisture and temperature cause materials degradation and these effects cannot yet be reliably separated from effects caused by acid precipitation or various other air pollutants.[1]

UNDETERMINED EFFECTS

Beyond the alteration of the chemistry and biology of certain sensitive surface waters, the other effects of acid deposition in eastern North America are undetermined.[1] Why are they undetermined? Either because they do not exist or because they have not or cannot be measured. If other small effects do exist, either adverse or beneficial, many of them may never be measured accurately because they may be overwhelmed by other variables in the environment or there may be insufficient baseline data to provide a standard against which to measure.

NO ACID PRECIPITATION PROBLEM IN THE WEST

No confirmed adverse effects from acid precipitation have been documented in the 17 western states. There is less research data available in the West than in the East, largely because it has not been considered a serious problem in the West. Precipitation monitoring data indicate that acid precipitation does occur in some western metropolitan areas, but this has been largely attributed to nitrogen oxides emitted primarily by motor vehicles. Rainfall acidity is also higher in some limited areas of high elevation mountain ranges in the West, but this appears to be related primarily to urban sources of nitrogen oxides and natural background acidity.

Rainfall acidity in the West is typically between 10 and 100 times less acidic than in the northestern U.S. based on data from the National Atmospheric Deposition Program.[6]

In 1980 the 31 eastern states accounted for more than 80% of U.S. SO_2 emissions and 66% of U.S. NO_x emissions.[7] The ratio of sulfates to nitrates in precipitation as well as their total representation is typically greater in the East than in the West.[6] Most electric utilities in the 17 western states are already subject to stringent emission limitations and they account for less than 10% of total U.S. utility SO_2 emissions. The primary source of NO_x emissions in both the East and the West is mobil sources.[7]

Although no adverse effects to surface waters from acid precipitation have been confirmed in the West, several investigations have identified limited high elevation mountain areas with surface waters that could be vulnerable to acid precipitation if it were to become as acidic as that occuring in the northeastern U.S.[8, 9] These areas include parts of the Cascade Mountains of Washington and Oregon, the Sierra Mountains of California and the Rocky Mountains of Colorado. However, no realistic scenario would increase western acidity to the extent experienced in the northeastern U.S.

Large areas of the West are characterized by arid or semi-arid region soils where potential evaporation and plant transpiration greatly exceed precipitation. These soils are not normally leached and do not naturally acidify. Adding acidic deposition to the soils will not change that or cause any forseeable ill effects. Most arid region soils are high in carbonate materials, have abundant exchangeable bases and can assimilate acidic deposition to an almost unlimited extent. These bases, particularly calcium and magnesium, also constitute a major portion of soil-derived airborne particulates which tend to neutralize acidic components in precipitation.

Sulfur in a variety of forms and in large quantities has long been used as a soil amendment in arid and semi-arid regions.[10] Approximately 10 million hectares of irrigated agricultural land in the 17 western states could benefit from the proper application of sulfur compounds to improve water infiltration, soil tilth or the availability of plant nutrients such as phosphorus and iron.[11, 12]

Research sponsored by the U.S. International Biological Program more than a decade ago concluded that rising levels of nitrogen-rich pollutants may well add beneficial plant nutrition inputs on western lands where small amounts of nitrogen are continually removed by grazing animals and cannot be replaced economically.[13] Overall, it appears that there may often be a greater probability for net beneficial effects than for adverse effects from acidic deposition if it were to occur in arid and semi-arid regions.

INTERAGENCY TASK FORCE RESEARCH PLAN

Research underway and planned by the Interagency Acid Precipitation Task Force appears to be on a track that will provide useful information on the acid precipitation problem. However, the effects research will continue to be hindered by at least two major factors:

1) Inadequate baseline data
2) Inability to measure small net changes in the ambient environment

The first of these factors will be met partially by the wealth of data currently being collected. However, there is a paucity of information that accurately quantifies past precipitation and surface water conditions.

The second factor will continue to resist resolution because other environmental variables and cycles will cloud possible effects of acid precipitation, whether adverse or beneficial. Although potentially beneficial effects may not be a reason to look favorably on acid deposition, to the extent that they may nullify potentially adverse effects, they also should be a consideration.

The potential for expediting research and pooling resources through interagency cooperation ought to be fully utilized. In the WRC states, such a cooperation is now being organized under coordination by Region 8 EPA. We are pleased with the effort by the Region 8 EPA Administrator to put together a background level of information through the cooperation of various agenies involved in several different studies. We in the West certainly need additional reliable data to know the circumstances in our region. We in the WRC stand ready to cooperate in these research activities.

LEGISLATIVE PROPOSALS AND WRC RECOMMENDATIONS

Two extreme reactions to the acid precipitation problem are to do nothing at all or to implement a massive emission reduction program based on the supposition that need and cost effectiveness could be shown sometime in the future.

To do nothing ignores the circumstantial evidence that implicates antropogenic emissions to acid precipitation in eastern North America. On the other hand, the implications of implementing a massive emission reduction program at this time without showing that it would solve the problem could prove to be a costly mistake. If enacted without opportunities for midcourse corrections responding to ongoing research and without emphasis on cost-effectiveness, such a program could needlessly expend tens of billions of dollars and have severe regional and national economic effects.

Although there appears to be no consensus regarding a solution to the problem, moderate approaches, given the level of scientific knowledge, include increased spending on acid precipitation research, the initiation of cost-effective mitigation such as liming of lakes, and a cost-effective emission reduction program phased to achieve early reductions at the lowest possible cost and to provide opportunity for reduction program reassessment and targeted to areas in the Northeast that have surface waters vulnerable to acidity.

Any large and permanent emission reduction program that might eventually ensue must be based on research results and allow enough flexibility so that the most cost-effective means are utilized. Although there is no scientific consensus regarding a solution to the problem, it is clear that a large SO_2 emission reduction based on scientific research and the benefits that would accrue, cannot be justified at this time. Current scientific knowledge has not established that major and irreversible adverse environmental effects have or will occur because of anthropogenic emissions. Circumstantial evidence does indicate there is an undetermined risk involved and this points to the need for additional and perhaps even accelerated research that might or might not justify emission reduction regulations in the future.

Premature regulatory action to reduce emissions could have several effects. If acid precipitation were found to result in widespread, costly and irreversible damage, reduced emissions might bring some early relief to the problem. On the other hand, costly emission reductions without proportional beneficial results could range from a moderate to a massive waste of money that would needlessly raise the utility bills of a large segment of the population. Some proposed legislation would unjustifiably spread the costs to the western states where major and costly emission reduction programs have already been implemented and where the potential for a future acid precipitation problem is significantly less than in the East. There is also proposed legislation that would dictate the method of emission reductions rather than allow for flexibility by sources to choose the most cost-effective means of compliance. This would further exacerbate the already unfavorable cost effectiveness of these proposals.

With the knowns and unknowns surrounding the acid precipitation problem and the overall uncertainty as to what course of action will produce beneficial results, prudence might dictate delay. However, we realize that given the nature of the circumstantial evidence of emission/deposition linkages, the level of public opinion regarding the issue and today's political reality, action may not wait for more substantial data. Therefore, we recommend that if any legislation is enacted it should adhere to the following principles: 1. Move ahead with research to provide the adequate scientific basis upon which to reassess and make long term policy decisions. 2. In the meantime, any reductions should be phased, based upon what we do know, targeted in the East, and with increased mitigation measures as initial reductions are being achieved. 3. Permit flexibility in achieving SO_2 reductions and promote use of the most cost-effective methods available. 4. Avoid spreading the cost as it will drive the total cost of reductions up, exacerbate economic effects, penalize those who have already cleaned up, and probably delay the realization of a first phase of reductions by encouraging installation of control technology.

We appreciate this opportunity to present our views on the current state of scientific knowledge with respect to acid precipitation and are heartened that the Senate Committee on Energy and Natural Resources has focused on this topic. We firmly support valid scientific analysis and trust it can and will be a major consideration as political decisions on acid precipitation are made now and as more information is learned in the future.

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Senator **Warner**. Thank you for the very clear and concise statement.

Now, Mr. Thomas Altmeyer, vice president, congressional and government affairs, Mining and Reclamation Council.

STATEMENT OF THOMAS ALTMEYER, VICE PRESIDENT, CONGRESSIONAL AND GOVERNMENT AFFAIRS, MINING AND RECLAMATION COUNCIL OF AMERICA

Mr. **Altmeyer**. Thank you, Mr. Chairman.

MARC is a national association, as you know, Mr. Chairman, of coal producers and allied industries representing over 200 companies and 32 State and regional coal associations.

Through its corporate membership and affiliated associations, MARC represents over 3,000 coal operators and industry suppliers nationwide. We appreciate the opportunity to present our views to the committee and the interest of the committee in holding this hearing.

Acid rain is considered by many to be the major environmental issue of the 1980's. It is naive to think that such a complex problem is subject to a simplistic answer.

The complexity of the problem is exacerbated by its impact on national energy policy, the potential economic impact on regions of the country, and political considerations both domestically and with neighboring countries.

There is, however, a basic underlying theme which should guide congressional consideration of this issue. It is that a cure should not be prescribed before the disease is understood.

This theme was reflected in the testimony of the Administrator of the Environmental Protection Agency and the Secretary of Energy earlier this morning before the committee.

In addition to outlining the substantial ongoing research efforts to develop an empirical basis for prescribing a cure, Mr. Ruckelshaus reviewed the significant questions which must be addressed before deciding whether to initiate a multiyear, multibillion-dollar program.

While no amount of research will ever yield absolute answers, additional research, both into the phenomenon of acid rain and on technologies for most cost-efficient reductions of emissions from coal combustion, promise to provide a substantially enhanced information base upon which sound policy can be based.

The major question posed by this approach is, do we have time to develop that data base, and would it be irresponsible to act in advance of such knowledge?

MARC believes the answer is yes. While I am not a scientist and not qualified to analyze existing research, it is reasonable to say that neither adverse health effects, nor adverse effects on agriculture or forests have been documented as an impact of acid precipitation.

It is also significant, Mr. Chairman, to note that since 1970 sulfur emissions from stationary sources have decreased approximately 25 percent under existing law, in spite of increased power generation of 50 percent over the same period. Progress is being made.

No increase in emissions is projected, also we should note, in the near-term, emissions are projected to decline significantly beginning in the next decade.

What has been documented is that control proposals would have a significant impact on energy production and distribution with resultant increases in the cost of power generation in significant regions of the country.

It is ironic that while the traditional energy intensive industrial base of our country is losing markets, both domestically and abroad, we are contemplating increasing the cost of energy for speculative benefits.

It is accepted that high levels of acidity exist in waters in sensitive regions of the United States, and that these areas do have more acidic rainfall.

What is not known is whether a reduction in the level of acidity of rainfall in these areas will result in any corresponding change in the acidity level of affected waters.

As reflected by the National Academy's acid rain study, the relative contribution of local and distant sources of SO_2 and nitrous oxide emissions to the pH level of rainfall and whether the rainfall directly impacts the acidity level of affected waters is not known.

Given this existing knowledge and projected trends of emissions, we do have time to develop a better information base prior to deciding whether to initiate an additional control program. And we do have time to develop more environmentally efficient emission reduction technologies rather than mandate in the extremely costly retrofit of existing sources to achieve reductions for a limited period.

For these reasons, Mr. Chairman, MARC is opposed to legislative proposals to impose multiyear reductions on sulfur emissions from stationary sources.

We are specifically opposed to any federally mandated technology or regulatory requirement on existing sources to reduce sulfur dioxide emissions.

MARC believes that the private sector, with its inherent competitive forces, is best equipped to determine the most cost-efficient and workable compliance technology to meet any emission reduction standards established by the Congress.

Given the level of scientific knowledge, initiation of a massive reduction program at this time is neither justified, nor supportable.

Under S. 768, which has been reported by the Senate Environment Committee and similar proposals, billions of dollars would be required to be expended which may result in no improvement to the problems sought to be addressed.

A more progressive course of action, Mr. Chairman, would be to address the problem of acidified waters immediately through mitigation and to aggressively move forward with research programs as proposed by Senator Byrd and others in S. 1925, upon this hearing, which you were at, Mr. Chairman, explored the various technologies for better coal combustion research, and to develop and demonstrate more cost-efficient technologies to enhance not only combustion efficiency, but reduce emissions from stationary sources.

One part of the debate on acid rain that has not been adequately addressed and is why it is heartening that this committee is holding hearings is that this legislation has a substantial impact on the national energy policy which evolved, in large part, from this committee through the decade of the 1970's. That policy is premised upon the utilization of domestic resources as coal for energy production.

To meet that goal, increased emphasis must be placed on developing precombustion, combustion, and postcombustion technologies through the commercial demonstration stage to permit coal for the use of power generation with reduced emissions.

Through development and implementation of enhanced technologies for more efficient and environmentally inert use of coal, coal will continue to provide low-cost energy for America. This course of action will work to simultaneously pursue and achieve both our Nation's environmental and energy policies.

Mr. Chairman, we thank you for the opportunity to present our views.

[The prepared statement of Mr. Altmeyer follows:]

STATEMENT
MINING AND RECLAMATION COUNCIL OF AMERICA
BEFORE THE
COMMITTEE ON ENERGY & NATURAL RESOURCES
U. S. SENATE
APRIL 30, 1984

MR. CHAIRMAN, MEMBERS OF THE COMMITTEE, I AM THOMAS ALTMEYER, VICE PRESIDENT FOR CONGRESSIONAL AND GOVERNMENT AFFAIRS OF THE MINING AND RECLAMATION COUNCIL OF AMERICA (MARC). MARC IS A NATIONAL ASSOCIATION OF COAL PRODUCERS AND ALLIED INDUSTRIES REPRESENTING OVER 200 COMPANIES AND 32 STATE AND REGIONAL COAL ASSOCIATIONS. THROUGH ITS CORPORATE MEMBERSHIP AND AFFILIATED ASSOCIATIONS, MARC REPRESENTS OVER 3,000 COAL OPERATORS AND INDUSTRY SUPPLIERS NATIONWIDE. MARC APPRECIATES THE OPPORTUNITY TO PRESENT ITS VIEWS TO THE COMMITTEE.

IN THE LIMITED TIME AVAILABLE, I WILL REVIEW MARC's POSITION ON CURRENT LEGISLATION MANDATING REDUCTIONS IN SULFUR DIOXIDE AND NITROUS OXIDE EMISSIONS FROM STATIONARY SOURCES; HIGHLIGHT THE MAJOR CONCERNS RAISED BY VARIOUS PROPOSALS; AND SUGGEST A COURSE OF ACTION FOR THE THE COMMITTEE'S CONSIDERATION.

ACID RAIN, CONSIDERED BY MANY TO BE ONE OF THE MAJOR ENVIRONMENTAL ISSUES OF THE 1980'S IS ONE OF THE MORE COMPLEX ENVIRONMENTAL ISSUES TO FACE THE CONGRESS. IT WOULD BE NAIVE TO THINK THAT SUCH A COMPLEX PROBLEM IS SUBJECT TO A SIMPLISTIC ANSWER. THE COMPLEXITY OF THE PROBLEM IS EXACERBATED BY ITS IMPACT ON NATIONAL ENERGY POLICY, THE POTENTIAL ECONOMIC IMPACT ON REGIONS OF THE COUNTRY, AND POLITICAL CONSIDERATIONS BOTH DOMESTICALLY AND WITH NEIGHBORING COUNTRIES.

THERE IS, HOWEVER, A BASIC UNDERLYING THEME WHICH SHOULD GUIDE CONGRESSIONAL CONSIDERATION OF THIS ISSUE - IT IS THAT A CURE SHOULD NOT BE PRESCRIBED BEFORE THE DISEASE IS UNDERSTOOD. THIS THEME WAS REFLECTED IN THE TESTIMONY OF THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY AND THE SECRETARY OF ENERGY BEFORE THE COMMITTEE THIS MORNING. IN ADDITIONAL TO OUTLINING THE SUBSTANTIAL ONGOING RESEARCH EFFORTS TO DEVELOP AN EMPERICAL BASIS FOR PRESCRIBING A CURE, MR. RUCKELSHAUS REVIEWED THE SIGNIFICANT QUESTIONS WHICH MUST BE ADDRESSED BEFORE DECIDING WHETHER TO INITIATE A MULTI-YEAR, MULTI-BILLION DOLLAR PROGRAM.

WHILE NO AMOUNT OF RESEARCH WILL EVER YIELD ABSOLUTE ANSWERS, ADDITIONAL RESEARCH - BOTH INTO THE PHENONMENON OF ACID RAIN AND ON TECHNOLOGIES FOR MORE COST EFFICIENT REDUCTION OF EMISSIONS FROM COAL COMBUSTION - PROMISE TO PROVIDE A SUBSTANTIALLY ENHANCED INFORMATION BASE UPON WHICH SOUND POLICY CAN BE BASED. THE MAJOR QUESTION POSED BY THIS APPROACH IS DO WE HAVE TIME TO DEVELOP THAT DATA BASE AND WOULD IT BE IRRESPONSIBLE TO ACT IN ADVANCE OF SUCH KNOWLEDGE.

MARC BELIEVES THE ANSWER IS YES. WHILE I AM NOT A SCIENTIST AND NOT QUALIFIED TO ANALYZE EXISTING RESEARCH, IT IS REASONABLE TO SAY THAT NEITHER ADVERSE HEALTH EFFECTS NOR ADVERSE EFFECTS ON AGRICULTURE OR FORESTS HAVE BEEN DOCUMENTED AS AN IMPACT OF ACID PRECIPITATION. ALSO SIGNIFICANT IS THE FACT THAT SINCE 1970 SULFUR EMISSIONS FROM STATIONARY SOURCES HAVE DECREASED APPROXIMATELY 25 PERCENT UNDER EXISTING LAW IN SPITE OF INCREASED POWER GENERATION OF 50 PERCENT OVER THE SAME PERIOD; NO INCREASE IN EMISSIONS IS PROJECTED IN THE NEAR TERM; AND, EMISSIONS ARE PROJECTED TO BEGIN TO DECLINE SIGNIFICANTLY IN THE NEXT DECADE. WHAT HAS BEEN DOCUMENTED IS THAT CONTROL PROPOSALS WOULD HAVE A SIGNIFICANT IMPACT ON ENERGY PRODUCTION AND DISTRIBUTION WITH RESULTANT INCREASES IN

THE COST OF POWER GENERATION IN SIGNIFICANT REGIONS OF THE UNITED STATES. IT IS IRONIC THAT WHILE THE TRADITIONAL ENERGY INTENSIVE INDUSTRIAL BASE OF OUR COUNTRY IS LOSING MARKETS BOTH DOMESTICALLY AND ABROAD, WE ARE CONTEMPLATING INCREASING THE COST OF ENERGY FOR SPECULATIVE BENEFITS.

IT IS ACCEPTED THAT HIGH ACIDITY LEVELS EXIST IN WATERS OF SENSITIVE REGIONS OF THE UNITED STATES AND THAT THESE AREAS DO HAVE MORE ACIDIC RAINFALL. WHAT IS NOT KNOWN IS WHETHER A REDUCTION IN THE LEVEL OF ACIDITY OF RAINFALL IN THESE AREAS WILL RESULT IN ANY CORRESPONDING CHANGE IN THE ACIDITY LEVEL OF THE EFFECTED WATERS. AS REFLECTED BY THE NATIONAL ACADEMY OF SCIENCE'S ACID RAIN STUDY, THE RELATIVE CONTRIBUTION OF LOCAL AND DISTANT SOURCES OF SULFUR DIOXIDE AND NITROUS OXIDE EMISSIONS TO THE pH LEVEL OF THE RAINFALL AND WHETHER THE RAINFALL DIRECTLY IMPACTS THE ACIDITY LEVEL OF EFFECTED WATERS IS NOT KNOWN.

GIVEN EXISTING KNOWLEDGE AND PROJECTED TRENDS OF EMISSIONS, WE DO HAVE TIME TO DEVELOP A BETTER INFORMATION BASE PRIOR TO DECIDING WHETHER TO INITIATE AN ADDITIONAL CONTROL PROGRAM AND THAT WE DO HAVE TIME TO DEVELOP MORE ENVIRONMENTALLY EFFICIENT EMISSION REDUCTION TECHNOLOGIES RATHER THAN MANDATING THE EXTREMELY COSTLY RETROFIT OF EXISTING SOURCES TO ACHIEVE REDUCTIONS FOR A LIMITED PERIOD.

FOR THESE REASONS, MARC IS OPPOSED TO LEGISLATIVE PROPOSALS WHICH WOULD IMPOSE MULTIYEAR REDUCTIONS ON SULFUR EMISSIONS FROM STATIONARY SOURCES. MARC IS SPECIFICALLY OPPOSED TO ANY FEDERALLY MANDATED TECHNOLOGY OR REGULATORY REQUIREMENT ON EXISTING SOURCES TO REDUCE SULFUR DIOXIDE EMISSIONS FROM STATIONARY SOURCES. MARC BELIEVES THAT THE PRIVATE SECTOR, WITH ITS INHERENT COMPETITIVE FORCES, IS BEST EQUIPPED TO DETERMINE THE MOST COST EFFICIENT AND WORKABLE COMPLIANCE TECHNOLOGY TO MEET EMISSION STANDARDS ESTABLISHED BY THE CONGRESS.

RECOGNIZING THE PROBLEM OF ACIDIFIED WATERS IN SENSITIVE REGIONS OF OUR COUNTRY AND THE LIKELY CONTRIBUTION OF SULFUR EMISSIONS MARC SUPPORTS EFFORTS TO EXPEDITIOUSLY RESOLVE THE SCIENTIFIC UNCERTAINTIES IN OUR KNOWLEDGE AS THAT BEING CONDUCTED BY THE NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM.

GIVEN EXISTING SCIENTIFIC KNOWLEDGE, INITIATION OF A MASSIVE REDUCTION PROGRAM AT THIS TIME IS NEITHER JUSTIFIED NOR SUPPORTABLE. UNDER S.768 AND SIMILAR PROPOSALS BILLIONS OF DOLLARS WOULD BE REQUIRED TO BE EXPENDED WHICH MAY RESULT IN NO IMPROVEMENT TO THE PROBLEMS SOUGHT TO BE ADDRESSED. A MORE PROGRESSIVE COURSE OF ACTION WOULD BE TO ADDRESS THE PROBLEM OF ACIDIFIED WATERS IMMEDIATELY THROUGH MITIGATION AND TO AGGRESSIVELY MOVE FORWARD WITH RESEARCH PROGRAMS AS PROPOSED BY SENATOR BYRD IN S.1925 AND SENATOR MELCHER IN S.1278 TO DEVELOP AND DEMONSTRATE MORE COST EFFECTIVE TECHNOLOGIES TO ENHANCE COMBUSTION EFFICIENCY AND REDUCE EMISSIONS FROM STATIONARY SOURCES.

OUR NATIONAL ENERGY POLICY, WHICH EVOLVED IN LARGE PART FROM THIS COMMITTEE THROUGH THE DECADE OF THE '70'S, IS PREMISED UPON UTILIZATION OF DOMESTIC RESOURCES, AS COAL, FOR ENERGY PRODUCTION. TO MEET THAT GOAL INCREASED EMPHASIS MUST BE PLACED ON DEVELOPING PRE-COMBUSTION, COMBUSTION, AND POST-COMBUSTION TECHNOLOGIES THROUGH THE COMMERCIAL DEMONSTRATION STAGE WHICH PERMIT COAL USE FOR POWER GENERATION WITH REDUCED EMISSIONS. THROUGH DEVELOPMENT AND IMPLEMENTATION OF ENHANCED TECHNOLOGIES FOR THE MORE EFFICIENT AND ENVIRONMENTALLY INERT USE OF COAL, COAL WILL CONTINUE TO PROVIDE LOW COST ENERGY FOR AMERICA'S HOMES AND FACTORIES FOR HUNDREDS OF YEARS. THIS COURSE OF ACTION WILL WORK TO SIMULTANEOUSLY PURSUE AND ACHIEVE BOTH OUR NATION'S ENVIRONMENTAL AND ENERGY POLICIES.

Senator **Warner**. I thank you. And I thank all members of the panel for their very helpful and thoughtful contribution to this question.

We will now proceed to panel No. 5.

Mr. John C. Bard, president, the Aluminum Association; Edward L. Addison, president and chief executive officer of the Southern Co. on behalf of the Edison Electric Institute; Mr. Carl Bagge, president, National Coal; Michael Bergman, staff scientist, American Public Power Association; James C. Wilson, president, Rocky Mountain Energy Co. on behalf of Alliance for Clean Energy, Rosslyn, VA.

And I will also invite Mr. Quarles to come whenever he arrives and join with this panel.

Now, we will lead off, we will have Mr. Bard.

STATEMENT OF JOHN C. BARD, PRESIDENT, THE ALUMINUM ASSOCIATION

Mr. **Bard**. Thank you, Mr. Chairman.

My comments will emphasize the very damaging impact that pending acid deposition proposals would have on our industry.

Briefly stated, the bill, S. 768, reported by the Environment and Public Works Committee, would significantly increase electricity costs and drastically impair the present international competitiveness and future development of the U.S. aluminum industry.

This would result in reduced economic growth, lost jobs, lost tax revenues, trade imbalances, and a weakening of our country's industrial base.

As a major industrial user of electricity, our industry adds a voice that must be heard in the debate on acid rain.

The U.S. aluminum industry is a major basic industry, providing employment for almost half a million people in more than 700 plant locations in virtually every State.

Wages paid to our workers are among the highest in any industry. Primary production, the making of aluminum, is carried on in the Pacific Northwest, along the St. Lawrence Seaway, in the TVA service area, in the Ohio River Basin, in the gulf coast region and along the eastern seaboard.

The U.S. aluminum industry is preeminent in the world. We are today, however, faced with significant challenges from international competitors. These challenges are directly affected by U.S. Government policies. First and foremost, of course, are policies concerned with energy costs.

Aluminum smelters produce aluminum metal from alumina ore by using an electrolytic process which is both electricity dependent and electricity intensive. The production of aluminum is sensitive to energy costs and power rates determine our ability to compete in international trade.

Electricity costs represent one-third the cost of producing aluminum. On average, it takes 7.5 kilowatthours of electricity to make a pound of aluminum. Based on 1982 data, the average U.S. cost of electricity for aluminum production was estimated to be 2.4 cents, or 24 mills per kilowatthour, and in the last year this cost climbed even higher.

Our free world competitors, in contrast, pay an average of 1.7 cents, or 17 mills per kilowatt hour. Some foreign smelters, including Canadian smelters, pay as little as 3 mills. Foreign smelters, thus, already hold a large competitive advantage in terms of this major component of the cost of producing aluminum.

Power costs have a direct impact on aluminum capacity utilization worldwide and, therefore, on jobs. With a 7-mill disadvantage compared to free world competitors, capacity utilization in the United States during the recent recession was 20 percent less than most other free world producing nations.

During this recession, all but the industry's lowest cost facilities were closed or curtailed.

Proposed legislative approaches to the acid rain deposition issue will add tremendous costs to electrical generation.

Approximately 60 percent of the aluminum industry's capacity in the United States is located in the 31-State region covered by S. 768. Two-thirds of that capacity depends on coal-fired electricity, and will be directly affected by increased costs resulting from proposed SO_2 reductions.

An analysis conducted by the Aluminum Association shows that a reduction of SO_2 emissions by 8 million tons could increase the cost of electricity to some aluminum plants in the 31-State region by more than 10 mills per kilowatt hour.

This means an additional 7.5 cents per pound to the cost of producing primary aluminum. The Senate Environment and Public Works Committee voted for an SO_2 reduction of 10 million tons, a 25 percent increase in the reductions required by the original S. 768.

While aluminum production is energy-intensive, it converts electricity into a product that, through its light weight, strength, durability, corrosion resistance and recyclability, contributes greatly to our national well-being.

The aluminum industry takes pride in the fact that since 1972, we have reduced the amount of energy needed to make aluminum by 23.2 percent. These savings have been as important to the Nation as they have been to our industry's economic health.

We find, however, that in the debate on acid deposition, energy, economic and environmental concerns have become intertwined.

We urge the Congress to seek an answer that will not penalize major industrial users of electricity, such as aluminum, and will not penalize any one section of the country, either environmentally or economically.

In addition, proposals such as H.R. 5214, which would establish a nationwide acid deposition tax of 1 mill per kilowatt hour, would further damage the competitiveness of many aluminum facilities outside the 31-State region which have been identified as swing capacity; that is, operating only when aluminum demand is high.

An electricity surcharge to provide capital for controls in no way solves our problem. It would shift part of the burden of the cost of the cleanup to industrial segments in regions which did not contribute to the problem. In addition, the tax-base fund would not provide sufficient funding for the required investments.

All that does is shift the form of payment, and leaves the user in the same position I have already described, with very heavy operation and maintenance charges to be paid to utilities which must be absorbed in the price of aluminum. The ability to pass on these additional costs is severely limited. Aluminum is traded as a commodity on the open market.

Further, proposals to cap sulfur dioxide emissions are likely to have negative economic impacts on future development of production facilities and energy sources.

Such proposals raise serious questions concerning future growth, not only of our industry, but many others converting to coal within the 31-State region.

The aluminum industry strongly urges Congress to seriously weigh in its deliberation on acid rain legislation the inevitable result within industry of increased electricity costs, loss of jobs, loss of economic wealth and injury to a basic U.S. industry.

I want to thank you for giving us this opportunity to testify.

[The prepared statement of Mr. Bard follows:]

STATEMENT OF JOHN C. BARD
REPRESENTING
THE ALUMINUM ASSOCIATION
BEFORE THE
SENATE ENERGY AND NATURAL RESOURCES COMMITTEE

April 30, 1984

Thank you, Mr. Chairman. My name is John Bard. I am President of the Aluminum Association, Inc. I am pleased to have the opportunity to present the aluminum industry's views on acid rain legislation.

The Aluminum Association represents the U.S. aluminum industry. Its membership includes 10 of the 11 domestic producers of primary ingot, many producers of semifabricated aluminum products, foundries, secondary smelters and producers of aluminum electrical conductors. Association member companies account for virtually all of the domestic primary aluminum production and 85 percent of the shipments of U.S. semifabricated products.

My comments will emphasize the very damaging impact that pending acid deposition proposals would have on our industry. Briefly stated, the bill, S. 768, reported by the Environment and Public Works Committee would significantly increase electricity costs and drastically impair the present international competitiveness and future development of the U.S. aluminum industry. This would result in reduced economic growth, lost jobs, lost tax revenues, trade imbalances and a weakening of our country's industrial base.

As a major industrial user of electricity, our industry adds a voice that must be heard in the debate on acid rain.

The U.S. aluminum industry is a major basic industry providing employment for almost a half million people in more than 700 plant locations in virtually every state. Wages paid to our workers are among the highest in any industry. Primary production...the making of aluminum...is carried on in the Pacific Northwest, along the St. Lawrence Seaway, in the TVA service area, in the Ohio River Basin, in the Gulf Coast region and along the Eastern Seaboard.

The U.S. is by far the world's largest user of aluminum. Products of our industry are essential in every facet of American life: from containers and packaging to construction, transportation, electrical transmission, consumer durables, and machinery and equipment and, of course, defense. Ten percent of the products of the domestic aluminum industry are exported.

Aluminum is irreplaceable in many critical defense applications from aircraft and missiles to explosives. Advanced alloys, rapid solidification powder metallurgy and other technologies all lead to higher strength-to-weight ratio materials for better military performance.

The U.S. aluminum industry is preeminent in the world. We are today, however, faced with significant challenges from international competitors. These challenges are directly affected by U.S. Government policies. First and foremost are policies concerned with energy costs.

Aluminum smelters produce aluminum metal from alumina ore by using an electrolytic process which is both electricity dependent and electricity intensive. The production of aluminum is sensitive to energy costs and power rates determine our ability to compete in international trade.

Electricity costs represent about one-third of the cost of producing aluminum. On average, it takes 7.5 kilowatt hours of electricity to make a pound of aluminum. Based on 1982 data, the average U.S. cost of electricity for aluminum production was estimated to be 2.4 cents or 24 mills per kilowatt hour, and in the last year this cost climbed even higher. Our Free World competitors, in contrast, pay an average of 1.7 cents or 17 mills per kilowatt hour. Some foreign smelters including Canadian smelters pay as little as 3 mills. Foreign smelters thus already hold a large competitive advantage in terms of this major component of the cost of producing aluminum.

Power cost policies of other nations favor their domestic aluminum industries. In the past 25 years foreign government ownership of, or equity participation in, primary aluminum production has grown to more than 40 percent of the world's total capacity. Government-owned plants tend to stay in operation regardless of demand because of their goals of providing employment and generating foreign exchange. Aluminum smelters have been built in Africa, Asia, the Middle East, Oceania, and South America, near raw material sources and available low-cost power. This has caused the U.S. share of world primary aluminum production to shrink from about 42 percent to 28.6 percent in the period between 1960-1982. In other words, we are not competing in a fair and open market.

Power costs have a direct impact on aluminum capacity utilization worldwide and, therefore, on jobs. With a 7 mill disadvantage compared to Free World competitors, capacity utilization in the United States during the recent recession was 20 percent less than most other Free World producing nations. During this recession all but the industry's lowest cost facilities were closed or curtailed.

Proposed legislative approaches to the acid deposition issue will add tremendous costs to electrical generation. Approximately 60 percent of the aluminum industry's capacity in the United States is located in the 31-state region covered by S. 768. Two-thirds of that capacity depends on coal-fired electricity and will be directly affected by increased costs resulting from proposed SO_2 reductions.

An analysis conducted by the Aluminum Association shows that a reduction of SO_2 emissions by 8 million tons could increase the cost of electricity to some aluminum plants in the 31-state region by more than 10 mills per kilowatt hour. This means an additional 7½ cents/per pound to the cost of producing primary aluminum. The Senate Environment and Public Works Committee voted for an SO_2 reduction of 10 million tons, a 25 percent increase in the reductions required by S. 768.

While aluminum production is energy intensive, it converts electricity into a product that...through its lightweight, strength, durability, corrosion resistance and recyclability... contributes greatly to our national well-being. The aluminum industry takes pride in the fact that since 1972 we have reduced the amount of energy needed to make aluminum by 23.2 percent. These savings have been as important to the nation as they have been to our industry's economic health.

We find, however, that in the debate on acid deposition, energy, economic and environmental concerns have become intertwined. We urge the Congress to seek an answer that will not penalize major industrial users of electricity such as aluminum....and will not penalize any one section of the country either environmentally or economically.

In addition, proposals, such as H.R. 5314, which would establish a nationwide acid deposition tax of one mill per kilowatt hour would further damage the competitiveness of many aluminum facilities outside the 31 state region which have been identified as "swing capacity," operating only when aluminum demand is high.

An electricity surcharge to provide capital for controls in no way solves our problem. It would shift part of the burden of the cost of clean-up to industrial segments and regions which do not contribute to the problem. In addition, the tax based fund would not provide sufficient funding for the required investments. All that does is shift the form of payment and leaves the user in the same position I have already described with very heavy operation and maintenance charges to be paid to utilities which must be absorbed in the price of aluminum. The ability to pass on these additional costs is severely limited. Aluminum is traded as a commodity on the open market.

Further, proposals to "cap" sulfur dioxide emissions are likely to have negative economic impacts on future development of production facilities and energy sources. Such proposals raise serious questions concerning future growth not only of our industry but many others converting to coal within the 31-state region.

The aluminum industry strongly urges the Congress to seriously weigh in its deliberation on acid rain legislation the inevitable result within industry of increased electricity costs, loss of jobs, loss of economic wealth and injury to a basic U.S. industry.

Thank you again for granting us the opportunity to testify.

Senator Warner. Thank you very much. Mr. Quarles, you have joined us.

STATEMENT OF JOHN R. QUARLES, CHAIRMAN, NATIONAL ENVIRONMENTAL DEVELOPMENT ASSOCIATION'S CLEAN AIR ACT PROJECT

Mr. Quarles. Thank you, Mr. Chairman. I appreciate your letting me come on to this panel, and apologize that in trying to anticipate when your scheduling would work out, I misjudged.

I am Chairman of NEDA/CAAP, a separate organization of roughly 30 major national corporations and 15 building and trade and construction unions.

Our concerns have focused chiefly on the provisions in the Clean Air Act that would limit industrial growth. There are a number of provisions that we feel do not contribute to air quality and which, at the same time, severely burden companies that want to build new plants.

We have not become involved in the overall debate on acid rain. Although our general position has been that we feel the data base has not been sufficiently established as to whether controls would produce benefits to justify the commitments on such a broad-scale as S. 768 would make.

But today what I want to do is particuarly zero in on one feature of the bill that I suspect has been largely neglected by other witnesses; namely, that is the emissions cap.

Section 183 of S. 768 establishes an emissions cap. This is in addition to the basic provisions for a reduction program that also has provisions that state that no major stationary source in any of the area that is covered which began operation before January 1, 1981, shall increase its actual rate of emissions of sulfur dioxide over that experienced by such source during calendar year 1980, unless there is compliance with the complicated offsets requirements.

Now, that feature of this bill, in our judgment, is both unnecessary to the accomplishment of the purposes of the bill, even taking those purposes as defined by the proponents of the legislation; and, in addition, is likely to cause severe problems in the economy.

What the provision does is, it shifts the whole basis of regulation from the present basis, which sets maximum allowable emissions, to a different basis of what are the actual emissions. And that really changes a lot of things in the program, because the allowable emissions always relate to maximum operating conditions and maximum emissions that might occur, depending on the fuel that's used, as to whatever discussion is allowed by the regulatory provisions.

Whereas, actual emissions zero into the actual record of operation that a company might have experienced, or that a plant might have experienced during the calendar year 1980.

A lot of companies may not have been operating at full capacity. And if they are prohibited from increasing their actual rate of emissions over that experience in the base year, that could prohibit their increasing their production back up to full capacity.

Also, many companies may have a mix of different fuels that they're authorized to use. A particular plant may be equipped so that it could burn either coal or oil, or oil or natural gas. And companies may fluctuate back and forth depending on what the market conditions are or on other conditions.

Under the provisions of S. 768, that flexibility would be curtailed, and companies—or more specifically, plants that had used natural gas would be prohibited from switching to oil; plants that had used a particular grade of oil would be prohibited from going to a higher sulfur oil; plants that had used oil would likely be prohibited from shifting to coal. And so there would be a straitjacket that would be imposed on operations.

The impact that this would have on the market for fuel and national fuel policy and the pricing of fuel is something that has not beeen considered at all. And that is of particular concern to this committee, because it directly impacts the national energy policy, and yet I think there was no foundation laid for it at all in the decisions that are implicit in this bill.

Therefore, we welcome this committee taking an interest in this legislation.

Now, in addition to that effect of narrowing or restricting flexibility in the use of fuel, the bill would have a further severe economic impact by obstructing new plant construction and modernization or expansion of existing facilities.

It would impose the offsets requirements—and if you haven't been through the intricacies of the offsets requirements, you're lucky. I won't undertake on this occasion to try to explain them, but they are very complicated. They are difficult to comply with. And the companies would be prohibited from expanding their plants until they had complied with the offsets requirements everywhere.

Right now, the offsets requirements apply in nonattainment areas. This bill would have the effect of creating a 31-State nonattainment area for purposes of applying the offsets restrictions, and that would severely obstruct all sorts of modernization and expansion projects.

Now, finally, Mr. Chairman, the point that we would emphasize is that the need for this feature of the bill has not been established.

It has generally been premised on the assumption that sulfur dioxide emissions will be increased because of a lot of companies shifting to greater use of coal.

That assumption has been based on a number of modeling studies which, in turn, were based on the assumptions drawn from the marketplace about 5 years ago.

Under those assumptions, it is expected that coal prices would encourage greater shifts to coal.

The Council of Industrial Boiler Operators has, in our view, the best handle on what is actually happening in the marketplace. They do not anticipate this shift to coal-fired boilers throughout industry.

I would particularly call your attention to the appendices to my testimony, which set forth the actual history during the last 12 years, from 1970 to 1982, which flies in the face of the assumptions of these models.

The first chart of those contained in the appendix shows total sulfur dioxide emissions for the country for this 12-year period.

And it is evident that both the industrial emissions and utility emissions are declining during this period, and the total emissions are declining quite materially.

That has occurred, notwithstanding the fact that overall coal consumption has risen. And that's due in part to more use of controls. But there is no basis from these charts to expect that all of a sudden it's going to be a 180 degree turn and we'll start seeing much greater use of coal.

Now in particular, the third chart shows the coal consumption by the nonutility industries which has declined steadily from 1973 through 1982. And again, the projections of the models would suggest a complete turnaround in this.

The market conditions, if you actually go into the market and look at the reality, is totally to the contrary. So all of this is based on a set of modeling projections that are out of whack with what real data would suggest to us.

The modeling projections themselves based on assumptions that are now basically 5 years old. And if you will look at the real world rather than 5-year-old models, it will suggest to you we don't need this cap .

In view of the fact that we don't need the cap, we certainly shouldn't tolerate the adverse impacts on both economic activity and energy policy that would result from that cap.

And, therefore, we are strongly recommending to the committees of Congress and also to those who may consider this legislation should it be taken to the Floor that that feature of the bill be deleted.

Thank you very much.

[The prepared statement of Mr. Quarles follows:]

Testimony of
John R. Quarles, Chairman
National Environmental Development Association
Clean Air Act Project
before the
Senate Committee on Energy
and
Natural Resources

April 30, 1984

Mr. Chairman and Members of the Committee:

I appreciate the opportunity to appear before you today to present testimony on behalf of the National Environmental Development Association's Clean Air Act Project (NEDA/CAAP) on proposed amendments to the Clean Air Act. NEDA/CAAP is a coalition of industry and 15 trade unions of the AFL-CIO.

My testimony will focus on a narrow -- but potentially far-reaching acid rain issue. This growing issue is referred to as the "emissions cap" which is contained in S.768 which has been approved by the Senate Environment and Public Works Committee as well as several other acid rain bills. The significance of the emissions cap to this committee is that it will substantially affect patterns of fuel use and fuel pricing. In fact, any discussion of acid rain controls goes to the question of how industry will use fuels in the future to generate steam or electricity. As I discuss the cap, I will focus my comments on S.768 since it provides us with a specific example. However, the points I will make apply to any proposal offering an emissions cap.

During the past several years the national debate over acid rain has grown. That debate has focused attention on various adverse consequences of acid rain, possible strategies for reducing acid rain, and costs associated with these proposals. S.768 proposes an ambitious national control program designed to reduce emissions of sulfur dioxide from 1980 levels within the 31 eastern states by 10 million tons per year.

We are greatly worried that an acid rain cap such as contained in S.768's acid rain provisions in effect place a cap on production, obstructing the use and expansion of our national industrial capacity.

Section 183(c) of the Clean Air Act, as it would be amended by S.768, would provide, with the exception of coal conversions by utility boilers under the Fuel Use Act, that:

> "no major stationary source [within the 31-state region] which began operation before January 1, 1981, shall increase its actual rate of emissions of sulfur dioxide over that experienced by such source during calendar year 1980, unless [the source has complied with offsets requirements]."

This provision and related parts of S.768 establish the so-called "emissions cap" which is intended to prevent any increase in existing emissions.

We have several major concerns with the cap features of this bill. Our main concern is the emissions cap will be a cap on productive capacity and will cause a ripple of severe consequences disrupting normal industrial operations and growth throughout the 31-state region.

There are seven principal points which I will make today to illustrate the potential problems with a sulfur dioxide and nitrogen oxide emissions cap. They are:

- Current proposals fundamentally restructure parts of the Clean Air Act.

- An emissions cap will have the effect of restricting full use of existing industrial capacity.

- An emissions cap will restrict the ability of plants to switch fuels.

- An emissions cap will affect fuel pricing and patterns of fuel use.

- An emissions cap will limit new growth.

- An emissions cap provision does not properly integrate with other sections of the Clean Air Act.

- The premise supporting the need for an emissions cap is erroneous.

It is for these reasons that NEDA/CAAP strongly recommends that an emissions cap not be part of the proposed acid rain policy.

I. AN EMISSIONS CAP CHANGES THE BASIS OF THE CLEAN AIR ACT

Limiting emissions to historic and actual levels, as proposed by the emission cap under S.768, will fundamentally restructure how emissions have been permitted and regulated under the Clean Air Act, causing a number of dislocations and problems.

When an applicant applies for a permit, both he and EPA look at the size of the plant, the fuel being used, the production level of the plant, and available emission controls. Generally, it is assumed the plant will operate at its full capacity. EPA issues the applicant a permit which specifies the maximum allowable emissions from the plant based on these factors, recognizing that actual emissions will fluctuate and often be well below allowable levels. Standard permit conditions require that emissions control equipment be operated at all times so a company cannot take advantage of lower production levels to cut back on pollution control.

Under the emissions cap proposal contained in S.768, the permitting system will change from one which depends on the production level at which a plant is designed to operate (as described above), to one based on the production level at which a plant has actually operated over a specified historic period.

This change will have serious, disruptive results which I will now describe.

II. AN EMISSIONS CAP CAN RESTRICT FULL USE OF PRODUCTIVE CAPACITY

The most severe, unfair, and socially disruptive effect of the proposed legislation would occur if it should be applied in a manner to prevent facilities from operating at full capacity, as the language of the proposed section 183(c) suggests. That language states that no source shall increase its "actual rate of emissions" over calendar year 1980 without first acquiring offsets.

The clearest example of a regulatory miscarriage will occur if a facility which was operating only at partial capacity due to lack of demand for its production or because of other factors during the base year is restricted from operating at full capacity under these proposed restrictions. For example, a company operating at 70 percent capacity in the base year would not be able to expand to its full 100 percent production. To use the remaining 30 percent capacity, the company would have to treat the unused part of the plant as a new source under the Clean Air Act and apply for new permits and satisfy offset requirements.

The result would be especially harsh if a plant has laid off workers and is prevented from rehiring them to return to normal operations. In addition, this restriction could interfere with many other types of relatively minor normal operating changes, which may increase emissions over the base year yet remain within allowable limits. In short, the danger that the emissions cap may preclude maximum use of existing industrial capacity must be avoided.

III. AN EMISSIONS CAP WILL INTERFERE WITH FUEL USE

Fuel use is a fundamental component of nearly all major industrial operations. For most industrial plants, on-site fuel combustion represents a substantial operational element having air quality significance, and many such facilities are designed with flexibility to use alternate types and grades of fuel. Thus an industrial plant may have existing equipment and regulatory approval, which permits it to shift between coal and oil or between oil and natural gas, or possibly among all three, in addition to shifting between various grades of fuel with respect to their sulfur content.

It is also of critical importance to recognize that many industrial plants have "interruptible" natural gas supply agreements, and that although they may normally burn natural gas they also are permitted to burn other fuels such as oil. If the gas supplier for any reason cuts off the gas, a user must be able to switch quickly to an alternate fuel, which could result in a slight increase in emissions. If it cannot do so, it may be forced to shut down.

The apparent effect of section 183(c) as set forth in S.768 will be to freeze patterns of fuel use on the basis of 1980 operations. That would deprive numerous industrial facilities of important elements of operating flexibility. It would impose such effects on a rigid and arbitrary basis.

An example of this problem within our membership is a refinery which after two years of environmental monitoring and negotiation received a permit allowing it to burn heavy fuel oil, fuel gas, and natural gas and to emit 0.6 lbs/mmBTU annual average. Because of the current abundant supply of natural gas and fuel gas, actual emissions dropped to 0.2 lbs/mmBTU by 1980. Should supplies of refinery fuel gas or natural gas become limited, the refinery would not be able to return to burning heavy fuel oil if it was subject to an emissions cap based on 1980 levels --

even though the current permit would allow it.

A similar situation exists in another member's chemical plant. If an emissions cap is based on actual SO_2 emissions in 1980, more than 75 percent of the plant's installed capacity will be subject to gas availability and cost. About 2500 workers could lose their jobs if natural gas becomes unavailable and the plant is not able to switch to an alternate fuel.

IV. AN EMISSIONS CAP WILL AFFECT FUEL PRICING AND PATTERNS OF USE

An emissions cap is likely to cause increases in certain fuel prices. For plant boilers which are capable of burning both oil and natural gas, boiler owners will normally switch back and forth from oil to gas depending on fuel price. If a plant is limited to burning natural gas due to an emissions cap, the ability to switch fuels is eliminated. This limits the ability of the boiler owner to negotiate fuel prices. One company estimates that without the ability to bargain oil prices against natural gas prices, the price of natural gas would rise 5 percent.

An emissions cap can also limit the availability of fuels. An emissions cap in effect places a ceiling forever on the use of fossil fuels such as oil and coal. Since emissions cannot rise, there will be a heavy demand for low emitting fuels such as natural gas and away from coal and oil. You would expect both availability and price effects to occur.

The impact of these environmental controls in potentially altering long-term patterns of fuel utilization and pricing may be of major significance to national energy policy. This impact appears not to have been considered at all to date and certainly warrants careful review by this committee.

V. AN EMISSIONS CAP WILL LIMIT NEW GROWTH

The cap, regardless of whether it is based on actual or permitted emissions, will act as a disincentive to new growth.

It will further complicate the regulatory process for approving construction projects to expand industrial facilities. The acid rain proposals will have the effect of establishing a 31-state nonattainment region in which any new project will require offsets. If that is the result, we believe the consequences will be extremely unfortunate. Without question, such a policy will severely hurt the economic vitality of the eastern United States. It is hard to imagine this effect is intended or that such an effect could be considered desirable in light of the limited benefit this would have to air quality enhancement.

Experience with the offsets requirements, as they have been in effect under the nonattainment provision of the Clean Air Act since 1977, has been most discouraging. In many instances, companies have succeeded in identifying offsets where they sought to expand an existing facility and could find offsets within that facility itself. By contrast, it has been rare that any company has succeeded in identifying and using off-site offsets. With all of the publicity about offsets trading, and all of the efforts to create banks and markets, few tangible results have been realized. The need to obtain offsets to permit an industrial expansion project presents a formidable obstacle. Experience indicates that if a system of offset requirements is established on a widespread basis, it will severely curtail normal economic development.

It is important to note that this feature, coupled with the other effects, will result in ironic conflicts among states. States which today have low SO_2 emissions due to extensive natural gas firing will be especially disadvantaged. For example, because of extensive natural gas use, many states in the South have low pools of SO_2 offsets to draw on, and therefore any new growth involving SO_2 emissions will be difficult, if not impossible.

VI. AN EMISSIONS CAP DOES NOT INTEGRATE WELL WITH THE CLEAN AIR ACT

In addition to these problems caused by a cap, there is another serious deficiency with S.768 and with other acid rain proposals: the inability to successfully relate an emissions cap to existing programs of the Clean Air Act. As the most conspicuous example, if an acid rain program is adopted which prevents SO_2 emissions from increasing, clearly PSD increments no longer make sense -- theoretically or practically. PSD is designed to limit "significant" increases in emissions. The acid rain programs which we have seen to date will make it illegal to have "any" increases, let alone insignificant increases.

Sponsors of acid rain proposals must give serious consideration to how the program will relate to other Clean Air Act programs. Failure to do so will subject the regulated community to confusing and contradictory requirements.

VII. THE NEED FOR AN EMISSIONS CAP IS QUESTIONABLE

Supporters of the cap on sulfur emissions base the need for controls on data projecting increases in emissions during the next two decades. According to some studies, the trend is that SO_2 emissions are decreasing with the exception of the 1980 to 2000 period. This forecasted increase is based on computer models which assume industry will increase its use of, and switch to, higher sulfur fuels. There is a fundamental problem with the projection that industry will increase coal use.

We believe the assumptions regarding increased use of coal in the non-utility sector are substantially overstated. The projected massive switch to coal by industry shows no signs of occurring. A recent study completed by the Council of Industrial Boiler Owners (CIBO) shows that EPA and other studies predict a much greater number of coal conversions than the boiler manufacturing industry forecasts. The studies appear to overstate conversions to coal by a factor of five, according to CIBO. This factor alone could substantially overstate the projected increase.

Historical data also do not support this upward trend in coal use for the industrial sector (see appendix). Facts show:

- o From 1973 through 1983 coal use by the industrial sector declined by 39 percent;

- From 1970 to 1982, industrial SO_2 emissions have declined 49 percent.

All these factors indicate that the trend is for decreasing industrial use of coal and level of SO_2 emissions. What is realistically going to reverse this trend so dramatically? Discussions within our membership, which is a broad-based industry mix, do not reveal any reason to suspect an upward trend in the use of coal. There is no economic or energy force to drive industry to make expensive coal conversions. The price differential between coal and other fuels does not justify converting.

Projections regarding increased industrial emissions in the 1990s depend on other major assumptions, too, including rate of replacing old plants with new, the role of nuclear power, GNP growth, conservation, the need for increased use of existing plants, and others. Each assumption is that -- precarious at best, and several of them besides coal conversion rates will almost certainly not hold. A case in point is energy conservation. The models have assumed there will be little increased energy conservation. Yet from 1973 through 1983, the energy consumed per dollar of GNP -- a measure of energy conservation -- declined 22 percent. We believe energy conservation will continue to increase rather than remain flat, as the models assume.

Based on these overstated assumptions, the entire basis for needing an emissions cap may be wrong.

CONCLUSION

An emissions cap will have serious consequences for industry, employment, and energy use. Under S.768, the Committee chose a year at the start of the recession and in effect freezing production at the levels of that year. Acid rain emissions caps will make it against the law in many cases to use 100 percent of installed capacity -- capacity previously approved under the Clean Air Act permitting process. Increased production will be prevented despite the fact that no human health or environmental harm would result.

Congress will be establishing not only an emissions cap, but also a production cap. The far-reaching consequences of adopting an emissions cap similar to S.768 provisions must be clearly understood from the start.

As I have discussed, the cap will lock some companies into reduced product output, prevent new growth, and limit industry's choice of fuel uses, increase fuel prices and changes fuel use patterns.

It follows that unemployment problems may be widespread. If companies are prevented from operating at full capacity or expanding their plants, they will be unable either to recall employees who were laid off or hire new employees. This effect on employment cannot be overlooked.

Additionally, a cap based on actual emissions is arbitrary and will have inequitable impacts on industry. Choosing an arbitrary year to base an emissions cap will affect industry in different and unequal ways. If the year chosen was a recession year, a large number of industries will be hurt. But even if the year chosen was a good economic year, some industries probably were not as well off as others, due to cyclical demand for their product and other reasons. The consequence is that all industry -- large companies and small businesses, heavy manufacturing and light manufacturing -- is likely to be treated unevenly and unfairly.

The effects of the emissions cap will exponentially increase the number of plants and constituencies regulated under an acid rain program. The initial intention of most proponents of acid rain controls was to focus attention only on those limited number of sources where significant reductions of SO_2 can be made. Under an emissions cap, every plant emitting SO_2 will be drawn into the acid rain regulatory program, even if only insignificant amounts of SO_2 are being emitted. Can a program function with such large numbers?

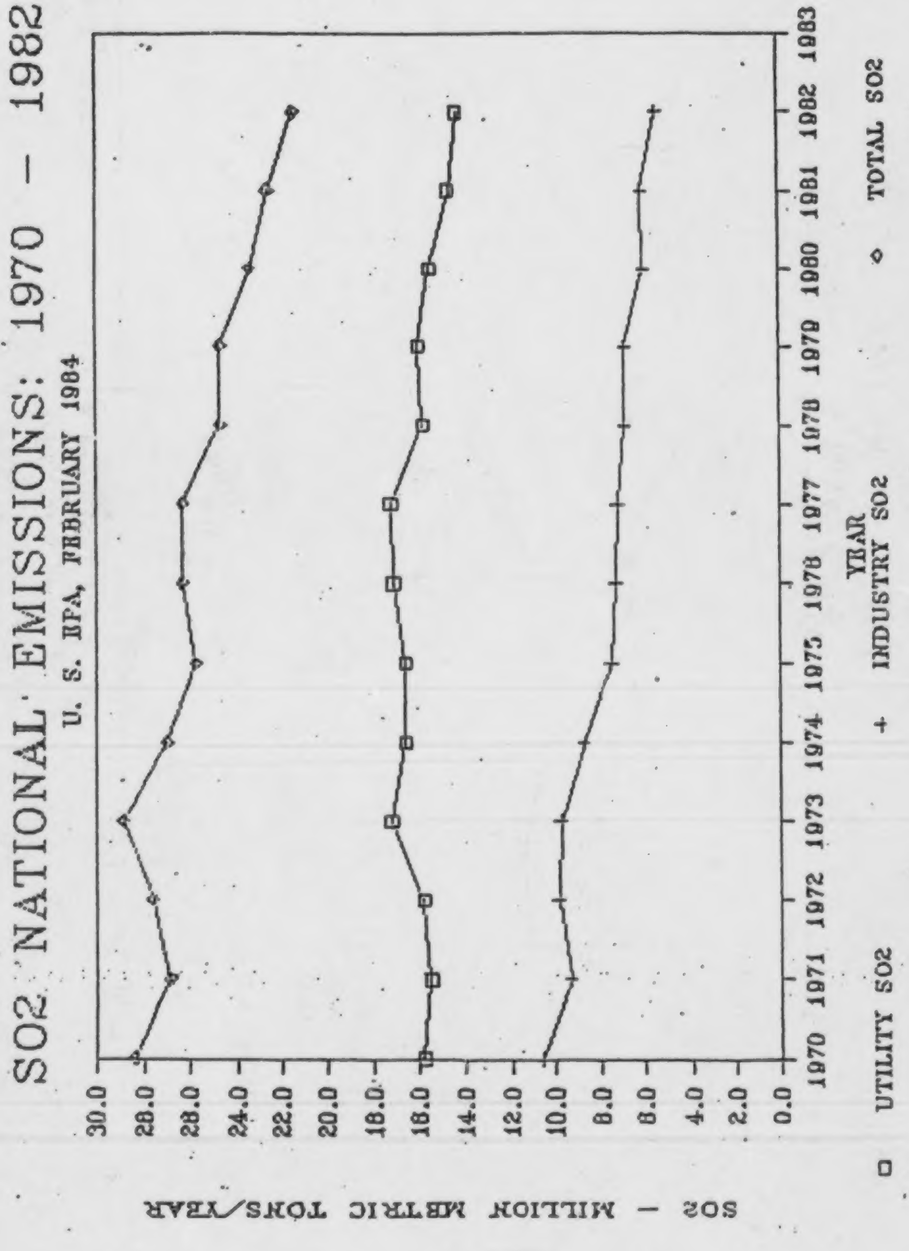
After evaluating these negative consequences of a production cap, the fundamental question remains: "Is it worth it?" Are the cap on production and its substantial costs worth levying controls when the whole premise for a cap is based on data clouded by uncertainty?

Projections on whether or not industrial emissions will increase in the 1990s depend on major assumptions. These include conversions to coal by industry, rate of replacing old plants with new, the role of nuclear power, GNP growth and the need for increased use of existing plants, and others, not to mention assuming the accuracy of emissions data.

Some of these assumptions almost certainly will not hold, such as that of the coal conversion rate. The projected massive switch to coal by industry shows no signs of occurring. Previously it was assumed the number of nuclear power plants would increase substantially; now it seems many plants will never be completed. Each assumption is just that -- precarious at best.

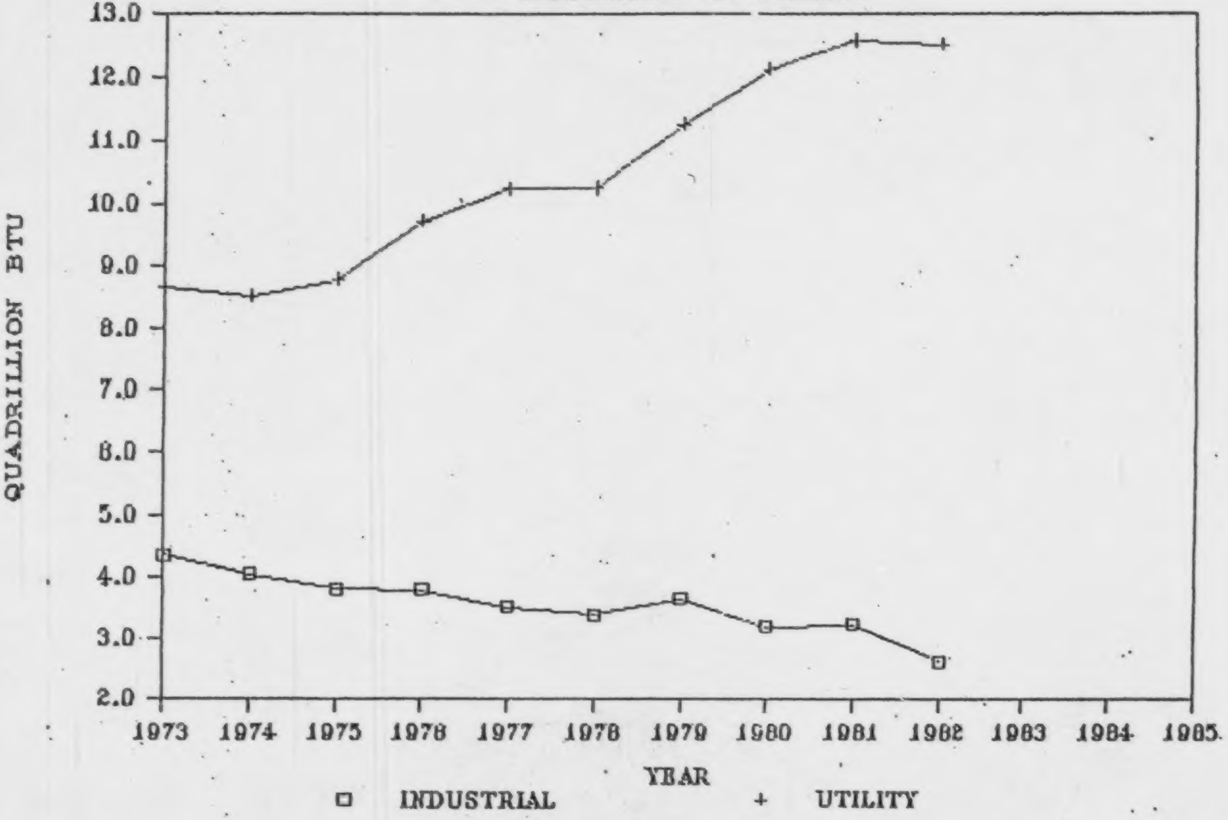
Congress must decide if freezing production at levels from a year characterized by recession, causing negative impacts on industry and employment, restructuring how emissions have been permitted under the Clean Air Act, and conflicting with the Act's PSD provisions are indeed worth the prevention of an increase that most likely will not occur.

APPENDIX


SO2 NATIONAL EMISSIONS: 1970 - 1982
U. S. EPA, FEBRUARY 1984
SO2 — MILLION METRIC TONS/YEAR
30.0
28.0
26.0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
YEAR
□ UTILITY SO2
+ INDUSTRY SO2
◇ TOTAL SO2

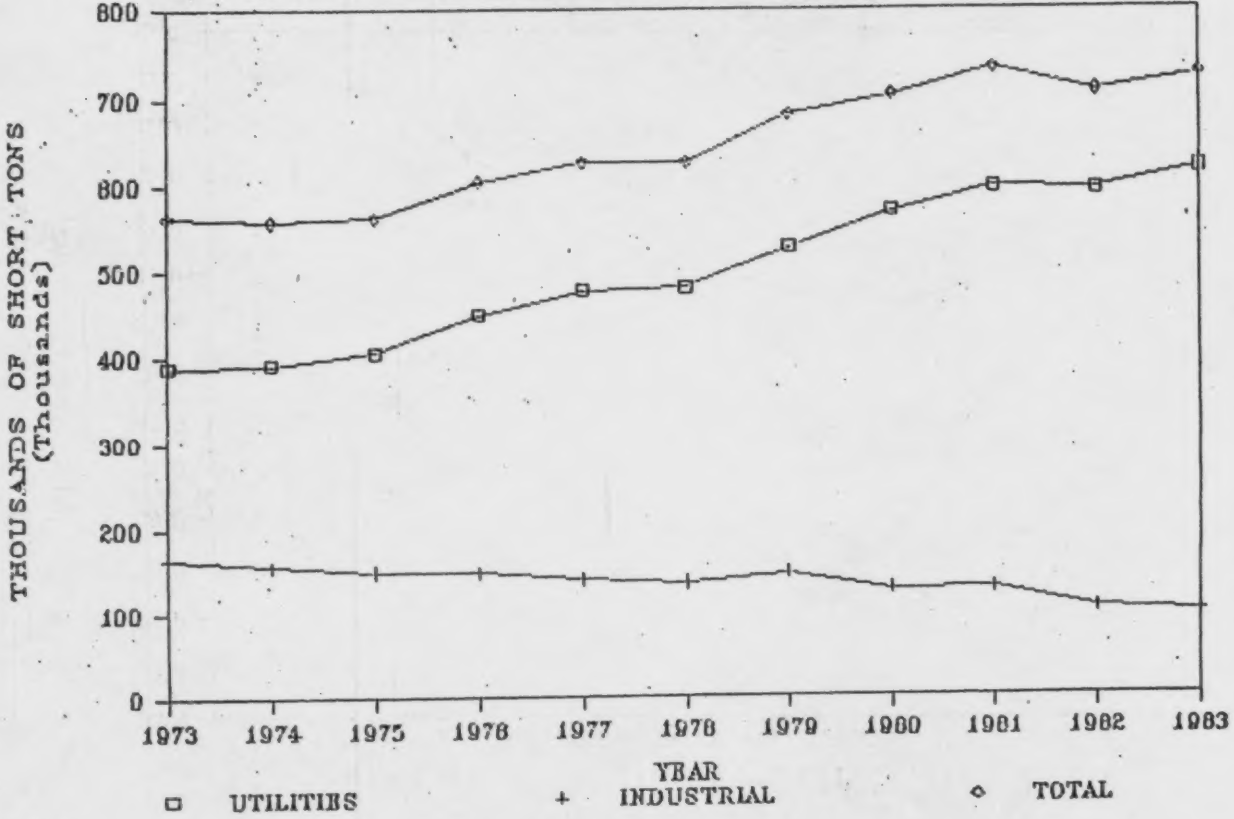
COAL CONSUMPTION

INDUSTRIAL VS. UTILITY



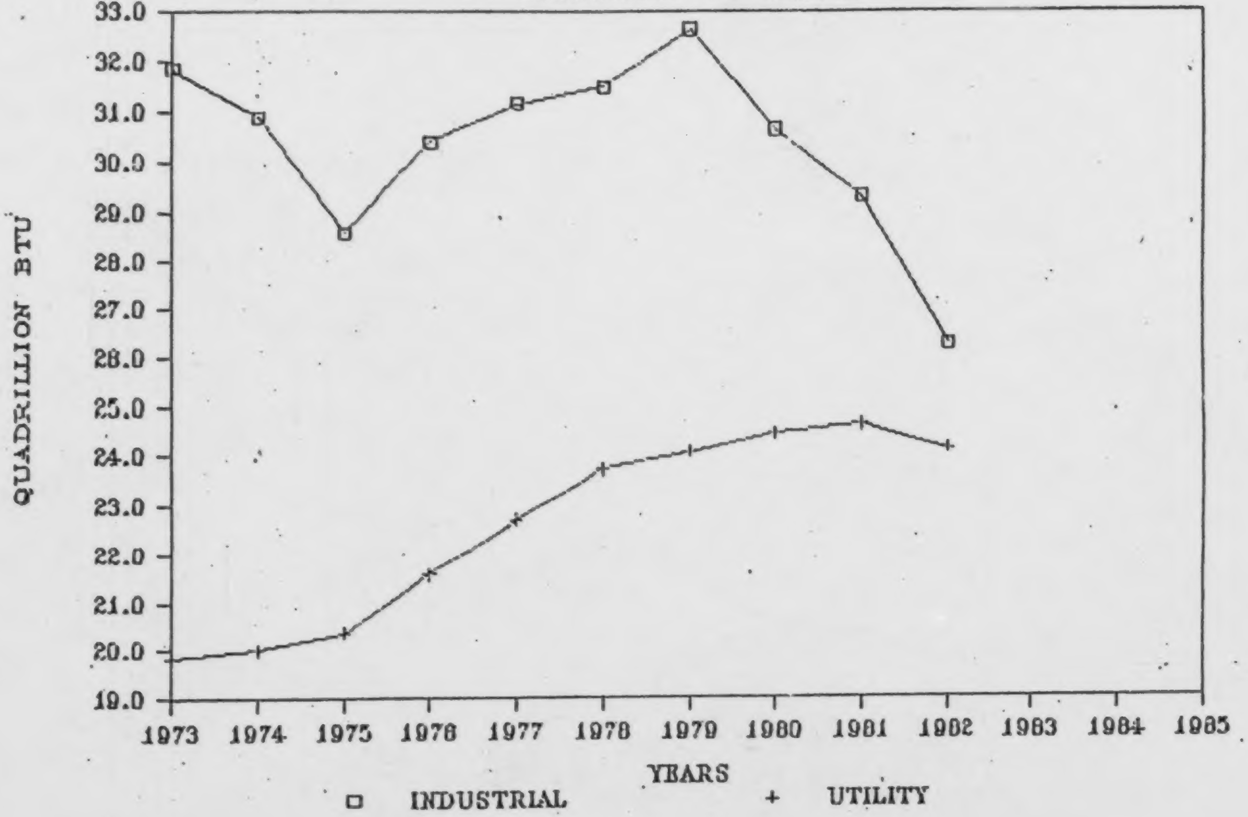
U. S. COAL CONSUMPTION

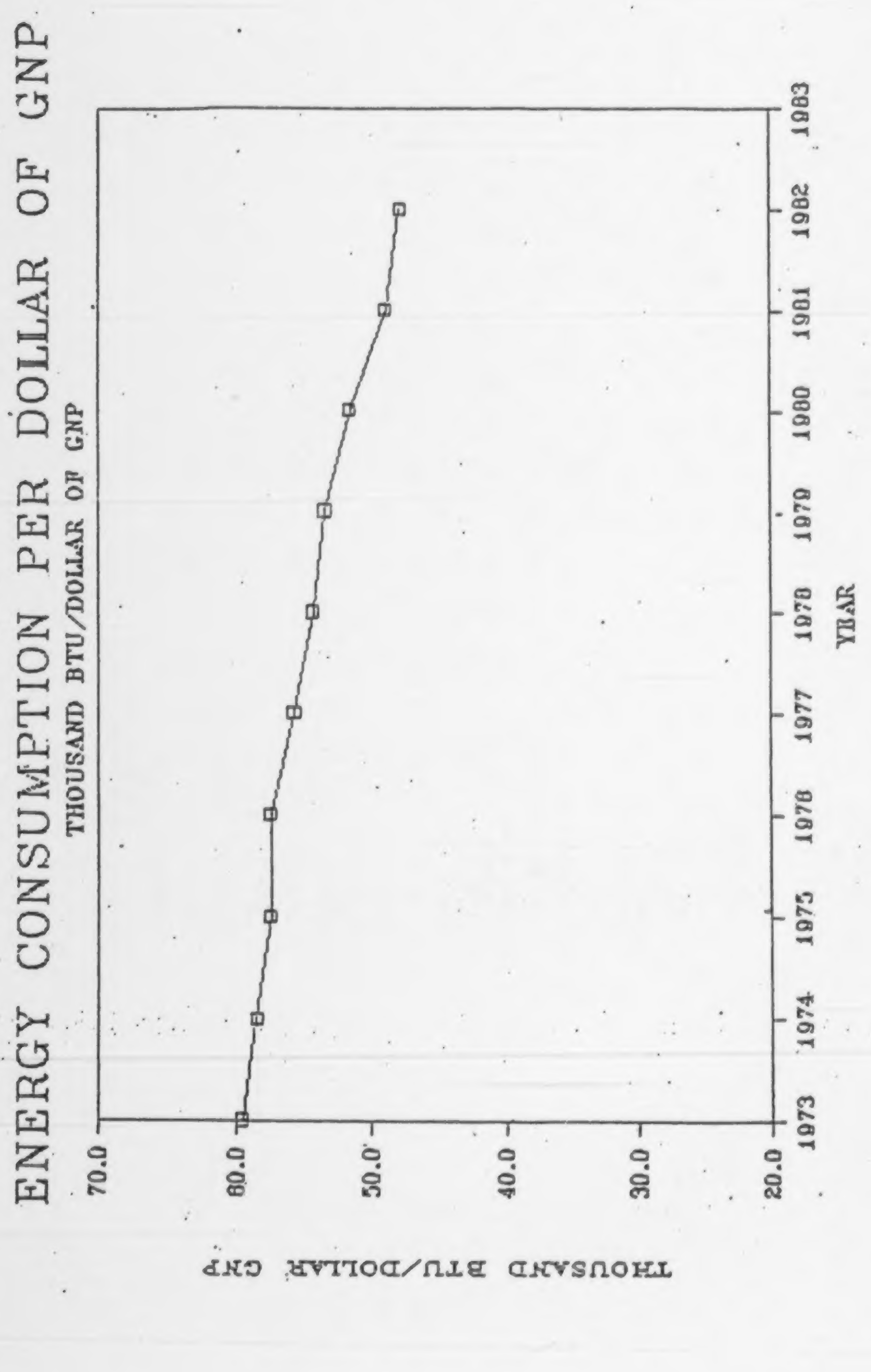
THOUSANDS OF SHORT TONS



TOTAL ENERGY CONSUMPTION

INDUSTRIAL VS. UTILITY




ENERGY CONSUMPTION PER DOLLAR OF GNP
THOUSAND BTU/DOLLAR OF GNP
THOUSAND BTU/DOLLAR GNP
70.0
60.0
50.0
40.0
30.0
20.0
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
YEAR

NATIONAL AIR POLLUTANT EMISSION ESTIMATES, 1940 - 1983
EPA-450/4-84-028
FEBRUARY 1985

(TERAGRAMS/YEAR)

SOURCE CATEGORY	1940	1950	1960	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
TRANSPORTATION																	
HIGHWAY VEHICLES	0.0	0.1	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.3	
AIRCRAFT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
RAILROADS	2.7	2.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
VESSELS	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3	0.2	
OTHER OFF-HIGHWAY	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
TRANS. TOTAL	2.9	2.3	0.4	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.0
STAT. SOURCE FUEL COMB.																	
ELECTRIC UTILITIES	2.2	4.1	8.4	15.8	15.3	15.8	17.2	16.6	16.8	17.1	17.2	15.7	16.0	15.5	14.7	14.3	
INDUSTRIAL	3.3	3.2	3.3	4.1	3.3	3.1	3.3	3.1	2.7	2.7	3.0	2.7	3.4	2.6	2.3	2.3	
COMMERCIAL	1.0	1.7	1.0	0.9	0.9	0.9	0.9	0.8	0.7	0.8	0.8	0.8	0.6	0.7	0.6	0.6	
RESIDENTIAL	2.3	1.9	1.1	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	
FUEL TOTAL	11.0	12.9	14.0	21.3	20.1	20.3	21.7	20.8	20.3	20.9	21.4	19.8	19.6	18.8	17.8	17.4	0.0
INDUSTRIAL PROCESSES	3.7	4.7	3.3	6.4	5.9	6.0	6.3	5.5	4.8	4.8	4.6	4.2	4.3	3.8	3.8	3.1	
SOLID WASTE DISPOSAL																	
INCINERATION	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OPEN BURNING	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
SOLID WASTE TOT.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MISCELLANEOUS																	
FOREST FIRES	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OTHER BURNING	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MISC. ORGAN. SOLV.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
MISC. TOTAL	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
TOTAL OF ALL SOURCES	18.1	20.4	20.1	28.0	26.5	27.0	28.1	27.0	25.7	26.1	26.3	24.6	24.4	23.1	22.3	21.4	
INDUSTRIAL TOTAL (PROCESS + FUEL BURNING)																	
INDUSTRIAL TOT.	9.2	9.7	6.7	10.5	9.4	9.1	9.8	8.7	7.5	7.3	7.2	6.9	6.7	6.0	6.1	5.4	

RGY CONSUMPTION

SUMPTION OF ENERGY BY THE INDUSTRIAL SECTOR
-QUADRILLION BTU-

RGY TYPE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983 (EST.)
AL	4.349	4.048	3.797	3.786	3.498	3.372	3.636	3.181	3.205	2.621	
TURAL GAS	10.388	10.003	8.532	8.761	8.636	8.539	8.549	8.394	8.257	7.109	
TROLEUM	9.132	8.720	8.182	9.043	9.809	9.905	10.582	9.535	8.308	7.907	
DROELECTRIC	0.035	0.033	0.032	0.033	0.033	0.032	0.034	0.033	0.033	0.033	
T COKE IMPORTS	-0.008	0.059	0.014	0.000	0.015	0.131	0.066	-0.037	-0.017	-0.023	
ECTRICITY SALES	2.341	2.337	2.346	2.573	2.662	2.761	2.873	2.781	2.817	2.542	
ECT. ENERGY LOSSES	5.610	5.700	5.665	6.197	6.476	6.735	6.912	6.751	6.677	6.083	
T. ENERGY CONSUMED	31.847	30.900	28.568	30.393	31.149	31.495	32.652	30.638	29.280	26.272	25.45

NSUMPTION OF ENERGY BY ELECTRIC UTILITIES
QUADRILLION BTU

ERGY TYPE	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983 (EST.)
OAL	8.658	8.535	8.786	9.720	10.243	10.236	11.264	12.122	12.583	12.517	
ATURAL GAS	3.748	3.539	3.240	3.152	3.284	3.297	3.609	3.807	3.764	3.335	
ETROLEUM	3.515	3.365	3.166	3.477	3.901	3.987	3.283	2.634	2.202	1.568	
YDROELECTRIC	2.975	3.276	3.187	3.032	2.482	3.110	3.107	3.085	3.033	3.538	
UCLEAR ELECT. POWER	0.910	1.272	1.900	2.111	2.702	3.024	2.715	2.739	2.974	3.084	
THER	0.046	0.036	0.072	0.081	0.082	0.068	0.089	0.114	0.127	0.108	
OTAL ENERGY INPUT	19.852	20.023	20.351	21.573	22.694	23.722	24.067	24.501	24.683	24.150	24.69

OAL CONSUMPTION - BITUMINOUS COAL, LIGNITE, AND ANTHRACITE
THOUSANDS OF SHORT TONS

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983 (EST.)
LECTRIC UTILITIES	389,212	391,811	405,962	448,371	477,126	481,235	527,051	569,274	596,797	593,666	618,318
OKE PLANTS(INDUST)	94,101	90,191	83,598	84,704	77,739	71,394	77,368	66,657	61,014	40,908	35,907
THER INDUSTRIAL	68,154	64,983	63,670	61,799	61,472	63,685	67,717	60,347	67,395	64,097	63,752

TIAL/COMM	11,117	11,417	9,410	8,916	8,954	9,511	8,388	6,451	7,421	8,240	7,600
TAL	562,584	558,402	562,641	603,790	625,291	625,225	680,524	702,729	732,627	706,911	726,696
USTRY TOTAL	162,255	155,174	147,268	146,503	139,211	134,479	145,085	127,004	128,409	105,005	99,659

ERGY CONSUMPTION PER DOLLAR OF GROSS NATIONAL PRODUCT(SEASONLY ADJUSTED)
THOUSAND BTU/DOLLAR OF GNP

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
IL & NATURAL GAS	45.7	44.3	42.8	42.8	41.6	40.3	39.1	37	34.3	32.9	
LL OTHER ENERGY	13.8	14.1	14.6	14.6	14.1	14	14.3	14.5	14.6	14.9	
OTAL ENERGY	59.5	58.4	57.4	57.4	55.7	54.3	53.4	51.5	48.9	47.8	
NP(TRILLION '72 $)	1.254	1.246	1.232	1.298	1.37	1.439	1.479	1.475	1.514	1.485	

Senator **Warner**. Thank you.

We will now hear from Mr. Edward Addison, president and chief executive officer of the Southern Co.

STATEMENT OF EDWARD L. ADDISON, PRESIDENT AND CHIEF EXECUTIVE OFFICER, THE SOUTHERN CO., ON BEHALF OF THE EDISON ELECTRIC INSTITUTE

Mr. **Addison**. Thank you, Mr. Chairman.

I have filed a complete statement which I would like to have entered into the record, if I may.

Senator **Warner**. Of course,

Mr. **Addison**. And after sitting here today and listening to the testimony I have heard, I'm going to summarize my summary, if I may, because we agree at the Edison Electric Institute with the majority of the testimony we have heard today which says to this committee that it's our position that we don't believe there is enough scientific evidence available today to justify going forward with a control program. And we believe that we need to do additional research, and we believe the evidence that we do have also indicates that we have ample time to do that. Because, indeed, quite a bit of the testimony talks about reductions in sulfur dioxide emissions and trends and acidic precipitatio that is heading in the right direction.

I would like to say to you that our industry is not just sitting idle while we urge others to do research. You have heard one witness already from EPRI talk about his particular budget. The budget there that the electricity utility industry is funding is really much larger than that for the 5-year period. In total acid rain related research, which goes to control methodology, included is $476 million.

That is a tremendous budget. And as he indicated to you, it is tied in with the work that is being done by the Federal Government and others.

And so we are strong supporters of the research program not only in talking about it, but in putting our money where our mouths are , so to speak.

Now, the other point that I would like to make to you is that the cost of this bill which you all have under consideration, the 10-million-ton reduction, would be very high.

EEI had a study prepared which indicates that the cost in 1993, the year when presumably we would be in compliance, would be somewhere between $8 to $12 million, a billion dollars a year in additional revenues.

The capital cost associated with that is somewhere in the neighborhood of $30 billion. Now, that is a tremendous amount of money.

In my company alone, which serves an area encompassing some 10 million people in Alabama, Georgia, Mississippi, and Florida, we find that our revenues would increase by $1.3 billion, which is about a 25-percent increase in 1993.

Now, Mr. Chairman, you have heard from the witness on my right about some of the burden that would impose on industrial customers, and about what it would do to our ability to compete in foreign markets, as well as to maintain our viability here at home. That range goes much further than that in our economy.

It goes all the way to retired people on fixed incomes who are having difficulty today paying their energy bills. I have had the dubious privilege, if you will, of sitting in a lot of rate increase hearings over the years, and it is not a very pleasant thing to sit through, and I can tell you that even those raises in electric rates which are necessary and not easy to come by, and when we talk about this kind of increase that could be a totally unproductive increase, then I think it needs all the study and research we can give it, and that is our position, sir.

Thank you.

[The prepared statement of Mr. Addison follows:]

Testimony of

Edward L. Addison

President

The Southern Company

on behalf of the

Edison Electric Institute

April 30, 1984

United States Senate

Committee on Energy and Natural Resources

Washington, D.C.

My name is Edward L. Addison, and I'm president and chief executive officer of The Southern Company, which has its headquarters in Atlanta, Georgia. I am testifying today on behalf of the Edison Electric Institute -- the national association of investor-owned electric utility companies.

The Edison Electric Institute includes utilities that serve 76 percent of the nation's electricity users.

Speaking for myself -- and as chairman of the EEI policy committee on environmental affairs -- I appreciate this opportunity to discuss the implications for national energy and economic policy of the acid rain proposals under consideration in the Senate.

Almost everyone refers to the underlying issue as "the *acid rain* problem." And the legislative proposals -- S. 768, for example -- have been called "*acid rain* bills." Actually -- as the members of the committee and its staff know -- these proposals are really *sulfur dioxide emissions* bills.

They are bills to reduce -- *even further* -- the levels of SO_2 emissions which *already* have been cut significantly during the past decade. And the reasons given for these proposals often center on conditions of acidity and aquatic life in a number of lakes in the Northeast.

I suggest that we keep these points in mind because the present state of scientific knowledge leaves a great many question marks hanging in the air between those SO_2 emissions and those lakes in the Northeast. Until these question marks have been replaced with facts, the Congress simply *cannot* design sound and effective legislation.

Hasty action which might well prove to be unnecessary or excessive would pose a serious threat to the national economy -- as well as to the clearly stated goal of the National Energy Policy Plan. And legislation like S. 768, in its present form, would effectively supersede key provisions of the Energy Security Act and other energy acts that originated or were shaped in this committee.

The Secretary of Energy -- Mr. Hodel -- has described the proposal to reduce SO_2 emissions by an additional 10 million tons a year as "...an expensive and disruptive new program -- of questionable necessity -- and uncertain benefit."

Now, the questions of necessity and benefit are certainly open for fair debate. But there can be no debate about describing the proposal as expensive and disruptive.

And given the pressures that my industry faces today, any unnecessary expense or disruption at this time would surely threaten the health of America's electric utilities. I hardly need to point out that a threat to the nation's electric utilities is a threat to the National Energy Policy goal -- the goal of providing an adequate supply of energy at a reasonable cost.

By speaking most directly to this committee's interest in energy supply and its effects on the economy, I don't want to give the impression that we disregard the environmental questions which have been raised.

We respect and share the national concern for a healthy environment. And we know that members of both the Senate and the House feel a proper responsibility to respond to that concern.

Therefore, I think it's important to state our position as clearly and as simply as possible. And that position is -- in these matters of sulfur dioxide emissions -- acid rain -- and the condition of lakes and waterways -- we are perfectly willing to follow the scientific facts -- wherever they lead. But first we need the facts.

What facts do we need? I could try to impress this committee with lengthy, detailed discussions of some of the scientific unknowns that remain to be resolved. There is, for example, the question of the relative importance of long-distance transport of emission products versus local sources of acid compounds in the atmosphere.

Or -- I could discuss the questions raised by what scientists have begun to learn about the acidity contribution of humus on the forest floor.

But -- rather than taking a great deal of time for complex technical discussion -- I prefer to follow the lead of Mr. William Ruckelshaus -- administrator of the Environmental Protection Agency. Mr. Ruckelshaus simply listed a few important questions that should be answered before large sums of money are committed to further controls.

There are questions about the scope of the problem -- questions about whether damage is increasing -- and if so, the question of pace: How quickly or slowly is change occurring?

There also are questions about precisely how damage occurs. And then -- the final, most important question which has not yet been answered: What are the best remedies available?

Mr. Ruckelshaus -- testifying before a subcommittee of the House of Representatives -- followed his list of unanswered questions with a statement that -- I believe -- goes to the heart of this committee's concern. He said, "These uncertainties and gaps in our knowledge are matters of far more than academic interest. They are directly relevant to responsible public policy choices."

By listing some questions which still need answers, I don't want to give the impression that we have no facts. A great deal has been learned in recent years. And the research that's going on right now indicates that we're on the way to learning a great deal more. But -- it's important for this committee and the Senate to know -- what we're learning does not support the contention that we must rush to regulate, and hang the cost.

For example, we know from a number of studies -- including recent U. S. Geological Survey reports -- that rainfall in New York State is not rapidly growing more acid -- and sulfate levels in some Adirondack streams are actually decreasing.

We also know that SO_2 emissions have dropped significantly under legislation that already exists. In fact, these emissions have decreased by about 25 percent below the levels of 1972 -- the peak year before the effects of 1970's Clean Air Act Amendments began to show.

In short -- the evidence now available just won't support the claim that we face a crisis situation which is quickly getting worse. The facts indicate clearly that -- whatever the nature and scope of any acid precipitation problem we may have -- this nation does not stand at the brink of an ecological disaster which demands instant action at any cost.

And the facts further suggest that the existing statutes which reflect the foresight of this committee and of the Congress are working -- statutes like the Clean Air Act, the Energy Security Act, and the National Acid Precipitation Act.

They are bearing fruit, in the form of reduced emissions and a growing body of scientific knowledge. Surely it makes a great deal more sense to continue a well-charted course that is working -- rather than to supplant it with a program that combines high costs and question marks.

On the basis of what I have discussed -- the facts that we have, and the questions that remain unanswered -- we can see no justification for saddling the American people and the American economy with a vast, new program of costly controls.

How costly? We have a number of estimates to choose from, depending on certain assumptions and variables. An analysis prepared for EEI by National Economic Research Associates concluded that it would cost the utility industry approximately $8 to $12 billion -- per year -- to achieve the level of reductions embodied in S. 768.

In my own system of companies -- which supply energy for 10 million people in four states -- we figure the additional construction costs alone could surpass $6 billion -- and customer rates could go up as much as 23 percent.

Now, you Senators frequently travel back to your home states to meet with constituents and see how things are going -- so I think you can well imagine the effect that an added burden of that size would have on most Americans. Consider, for example, the low-income family and the elderly couple on a fixed pension. Obviously, they cannot spend on food, clothing, and shelter the additional money they would have to pay for this program through their electric bills.

Consider, too, the impact on our economy through commercial and industrial customers. When these businesses must pay more for electricity, that cost will pass through to their customers in turn.

We would also see the effect of these higher energy costs reflected in the prices of the products we try to sell overseas. We're all aware of the problems posed by America's balance-of-trade deficit. Can anyone argue seriously that higher energy costs will help our country compete in world markets?

There's a further effect that would follow from the punitive nature of proposals like S. 768 -- proposals which concentrate the direct burden of compliance on one industry -- the electric utilities. By so doing, these proposals would undermine much of what the Congress -- and specifically, this committee -- has done to reduce American dependence on foreign energy sources.

Not one reputable body of scientists will guarantee that further drastic and costly reductions in SO_2 emissions from utilities will significantly lessen the acidity of lakes in the Northeast. But I can guarantee that they'll impose a severe penalty on the development and use of domestic energy resources -- specifically, the coal reserves which this nation enjoys in abundance.

So, on the one hand we have the costs and penalties of legislation like S. 768 -- which loom enormous. And, on the other hand, we have the stated aim of reducing the levels of acidity in certain lakes and streams -- which we cannot count on achieving. It is this total disparity between the costs -- and their certainty -- and the results -- and their uncertainty -- which leads us to oppose new measures to place further limits on SO_2 emissions from electric utility power plants -- at this time.

Does this opposition to the emissions control bills now in the Senate mean that America's electric utilities espouse a do-nothing policy on acid rain?

Not at all. We espouse a do-the-right-thing policy. And we believe the federal government is doing the right thing by pursuing an accelerated research program under the National Acid Precipitation Act. The Administration has proposed to invest more than $55 million on interagency research and development related to acid rain during the fiscal year 1985.

America's electric utilities are doing the right thing, too. We're combining our efforts and resources in acid precipitation research through the Electric Power Research Institute. During the next five years, this electric utility organization will invest $476 million in related research programs.

Indeed, these research programs provide our answer to any accusation that we're simply trying to evade the acid rain issue -- that we just want to research the question to death. Our research efforts -- and those of the federal government -- have specific timetables. Their focus is fixed on 1989. We genuinely believe the state of scientific knowledge by that time will provide clear answers -- or at least, clear indications of answers -- to many of the acid rain questions that science cannot answer today.

Meanwhile -- if I could leave only one thought with you -- it would be that we have the time to get those answers. There is no evidence that lakes which are acid have been rapidly getting more acid -- no evidence that the acidity of rainfall is rapidly increasing -- no evidence that our forests and soils are on the verge of collapse from the effects of acid rain. In these circumstances, we see no justification for rushing into law a program that could cost Americans billions of dollars every year -- a program that could penalize the development of domestic energy resources -- a program that offers no reasonable assurance it will achieve the goals which have been claimed for it.

I would be happy to answer any questions you might have.

# # # # #

(Rev. 4/24/84)

Senator **Warner**. Very clear and succinct.

Now, Mr. Bergman, Staff Scientist, American Public Power Association.

STATEMENT OF MICHAEL K. BERGMAN, STAFF SCIENTIST, AMERICAN PUBLIC POWER ASSOCIATION

Mr. **Bergman**. I'm Michael Bergman, staff scientist for the American Public Power Association.

With the chairman's permission, I would like to submit my full testimony to the record.

Senator **Warner**. It will be received.

Mr. **Bergman**. APPA is the national trade association for approximately 1,750 local publicly owned electricity utilities throughout the United States. About one out of every six Americans is served electricity by a nonprofit public power system.

APPA believes present scientific understanding supports these conclusions regarding acid precipitation: First, prudent action to control acid rain is justified now; second, the risks posed by acid rain are national in scope, and, therefore, the response must be national in scope; third, all fossil fuel combustion and metalic ore smelting likely contribute to impacts.

APPA supports national acid rain control legislation. However, as suppliers of electricity power, about two-thirds of which is derived from fossil fuels, public power systems have a responsibility to their consumer owners to see to it that the many billions of dollars associated with acid rain controls are fairly apportioned, and that a control program achieves its environmental objectives with minimum economic disruption.

Let me briefly summarize our understanding of the present status of acid rain science.

Acid rain—rainfall, that is, below pH 5.6 or so, has been observed in most parts of the globe. In the United States rainfall of pH 4.2 or so is relatively common in the Northeast, with more alkaline rainfall extending on a gradient to the South and to the West.

Man made and natural sulfur dioxide and nitrogen oxides can be transformed in the atmosphere to sulfuric and nitric acides.

The majority of sulfur compounds arise from the combustion of fossil fuels and from smelting metalic ores. Besides sulfur compounds and nitrogen oxides, chlorides, trace metals and hydrocarbons have all been implicated in the acid transformation pathway.

As well, many other natural and manmade compounds may cause acidity.

Loss of fish populations associated with acidification of surface waters has been documented in at least five areas round the globe, including the Adirondack Mountains and parts of Canada.

There are indications or tree growth reductions and seedling mortality in at least 16 countries with low pH rainfall.

Damage to materials from acid deposition has been documented for metals, building, stone, and statuaries, paints, and textiles.

Sulfur and other emissions from burning fossil fuels are also a contributor to a decreased visibility, as our natural and manmade hydrocarbons and ozone.

However, these statements do not draw a cause and effect relationship. And relating emissions to deposition and then to impacts cannot yet be accurately defined.

While over long periods and large geographic scales, emissions and acid deposition appear to be related in a linear fashion. Linearity does not hold under smaller spatial and shorter time scales.

The role and extent of dry deposition is also a major question mark. In terms of impact, soil acidification is a known natural process in humid regions, and may also be caused by forest disturbances. Natural weathering also counteracts acidifying processes, though at varying rates, under varying conditions at different sites.

Reduced forest growth is also known to be caused by ozone and trace mineral poisoning, and in some instances, such as the dieback of pines in the San Bernadino Forest in California, sulfur emissions are clearly not implicated.

In short, real impacts are occurring, but neither the precise role of acid precipitation, nor source-to-receptor relationships can yet be defined.

Many regions of the United States may be at risk from an incompletely understood set of environmental impacts.

Rather than defining the problem simply as one of SO_2 emissions and acid rain, the problem would be better viewed as a complex of impacts resulting from emissions from fossil fuel combustion and smelting metalic ores, sulfur compounds, chlorides, trace metals, nitrogen oxides, and hydrocarbons are all involved.

Why does APPA support national legislation? First, we believe the nature and possible extent of risks justify moderate action now. Second, we believe present legislative proposals before Congress do not adequately account for the scientific uncertainties, nor do they fairly apportion costs and responsibilities.

Mr. Chairman, APPA is the only national electricity utility organization to embrace a comprehensive program for dealing with acid rain. We are willing to take responsibility for the costs and requirements of acid rain controls in direct proportion to our responsibility.

APPA believes, based on the scientific indications I have just outlined, as well as on the more or less unanimous support from our members in all regions of the country, that a reasonable balance of the public interest in a clean environment and spending the fewest dollars to achieve it, and in dividing costs fairly can be achieved through legislation incorporating the following principles:

First; funding of emission reductions through a nationwide tax on SO_2 and NO_x emissions from all stationary and mobile sources for which an emissions tax is feasible;

Second, use of a least cost or freedom of choice emission reduction program;

Third, a two-phased program with implementation of the second phase to be triggered by affirmative congressional action;

Fourth, a structure to allow future growth, as Mr. Quarles was discussing.

Fifth, continued research and monitoring of the problem.

In addition, there should be a stronger national commitment to research and development in the area of fuels pretreatment, control technologies, cleaner generating technologies, such as fuel cells, and conservation.

These positions are offered in greater detail in my submitted testimony, and in its attached policy report of APPA's Special Task Force on Acid Rain.

I would be happy to entertain questions on any of the points I have raised. Thank you.

[The prepared statement together with additional questions and answers submitted by Mr. Bergman follows:]

Statement
by
Michael K. Bergman, Staff Scientist
AMERICAN PUBLIC POWER ASSOCIATION
before the
Senate Committee on Energy and Natural Resources
on the
STATE OF SCIENTIFIC KNOWLEDGE ON ACID PRECIPITATION
AND ITS LEGISLATIVE AND REGULATORY IMPLICATIONS

April 30, 1984

Mr. Chairman, thank you for this opportunity to present the views of the American Public Power Association on the current state of knowledge regarding acid precipitation and its legislative and regulatory implications. I am Michael Bergman, APPA Staff Scientist.

APPA is the national trade organization that represents approximately 1,750 local publicly owned electric utilities throughout the United States, Puerto Rico, the Virgin Islands, Guam, and American Samoa. About one out of six consumers in this country is served electricity by a public power system. As such, the Association is the largest consumer representative group for utility matters in the United States.

APPA itself does not conduct basic research in the area of acid rain. However, as suppliers of electric power -- about two-thirds of which is derived from fossil fuels -- to about 33 million consumer-owners nationwide, APPA's members have a responsibility to assess the acid rain problem and to ensure that the costs of any acid rain control program are fairly apportioned to achieve its objectives of preserving the environment with a minimum in economic disruption.

The Association's understanding of present science derives from continuous examination of the scientific literature, and from participation in the research and review activities of the Electric Power Research Institute (EPRI) and the Utility Air Regulatory Group (UARG). APPA endorses national acid rain control legislation which can meet reasonable standards of effectiveness, economy, and equity. The policy recommendations on acid rain legislation adopted by APPA's Special Task Force on Acid Rain in August, 1983, and endorsed by our Legislative and Resolutions Committee in February, 1984, flow from our understanding both of the present status of scientific knowledge and uncertainties, and of the political and economic parameters which must be taken into account by a control program.

However, the science of acid rain is more complex, and the conclusions which may be derived from the available evidence are more subtle and various, than the Association's policy recommendations can explicitly address. I therefore wish to make clear that the scientific observations and evaluations which follow are based upon the ongoing analysis of APPA staff, and do not each, individually and severally, represent an APPA policy position. APPA policy is, however, consistent with this evaluation.

The full text of the Policy Report of APPA's Special Task Force on Acid Rain and the Association's policy resolutions on acid rain and reauthorization of the Clean Air Act are attached to this testimony.

Mr. Chairman, I would therefore like to summarize APPA's understanding of the present state of scientific knowledge regarding acid precipitation, the implications this knowledge has for national acid rain control legislation, and the pressing research and development needs that remain.

I. PRESENT SCIENTIFIC KNOWLEDGE AND UNCERTAINTIES

While a scientific consensus seems to be emerging that acid rain is a problem and should be controlled -- as embodied in the 1983 panel study of the

National Academy of Sciences and the report of the White House's Office of Science and Technology Policy -- controversy still exists among reasonable and responsible scientists as to the causes, sources, extent, and effect of acid precipitation.

This controversy is unsurprising; acid rain may be the most complex environmental issue to date. A proper assessment of the risks and causes of acid rain requires the integration of knowledge in the areas of combustion chemistry, meteorology, atmospheric science, ecology, and ecosystem modeling. Each of these areas is extremely complex and incompletely understood. For example, understanding the nature of acid rain effects in natural environments requires knowledge of the carbon cycle, sulfur cycle, nitrogen cycle, trace metals and their role in aquatic and soil science, the dynamics of soil formation and natural acidification processes, the hydrology of watersheds, the physiology of hundreds of plants and animals and their reactions to stress, the role of past human activities such as reforestation and ecosystem disturbance, and many other factors -- all of which vary over space and time. And these considerations do not even address the questions of what pollutants are being emitted into the atmosphere, from which sources, and with what atmospheric transport and transformation characteristics.

Nevertheless, let me attempt to summarize, from the standpoint of an affected industry representing the ratepayer's interest, our understanding of the following questions about acid rain:

- What is known?
- What is indicated?
- What are key areas of disagreement?
- What can we conclude?

A. What is Known?

Rainfall below pH 5.6 (commonly assumed to be the acidity of "natural" rainfall) has been observed in many parts of the U.S. and over the globe. Rainfall as low as pH 3.8 has been observed at remote islands; Antarctica has shown values as low as pH 5.3; the French Alps have shown pH 4.2 to 7.0; and the Himalayas have shown values at pH 5.1. Acid fogs in Southern California have been as acidic as pH 2.0. Since a whole unit change in pH corresponds to a ten-fold change in hydrogen ion concentration, low pH can cause an alarming shock to the chemistry of many ecosystems. However, care must be exercised in comparing different pH readings, due to differences in sampling, analysis, and calculation protocols.

Man-made and natural sulfur dioxide and nitrogen oxides can be transformed in the atmosphere to sulfuric and nitric acids. Many other natural and man-made compounds may also cause acidity, including carbon dioxide, other sulfur and nitrogen compounds, sea spray, chlorides, and organic compounds.

In the U.S., rainfall of pH 4.2 or so is relatively common in the Northeast, with more alkaline rainfall extending on a gradient to the South and the West. Acidity in rainfall is dominated by sulfates in the eastern U.S., nitrates in the West. Sulfate and hydrogen ion are much higher in warm season precipitation in the eastern United States than in cold season precipitation.

Loss of fish populations associated with acidification of surface waters ("dead lakes") has been documented for five areas -- the Adirondack region of New York, the La Cloche Mountain region of Ontario, Nova Scotia, southern Norway, and southern Sweden. In the U.S., approximately 200 or so lakes have been so verified.

While there is no direct evidence that acid rain limits forest growth in either North America or Europe, there are indications of tree growth reductions and seedling mortality in areas with low pH rainfall. Countries for which declining forest yields or other adverse forest effects have been indicated include the United States, West and East Germany, Czechoslavakia, Poland, Romania, the Soviet Union, Yugoslavia, Switzerland, France, Italy, the Netherlands, the United Kingdom, Austria, Sweden, and Norway.

The common threads among the reports of declining forest growth are that the phenomenon is real; it is apparently occurring at an accelerating pace; and many different pollutants and mechanisms are involved at different sites.

Damage to materials from acid deposition has been documented for metals corrosion, erosion and discoloration of paints, decay of building stone and statuary, and weakening and fading of textiles.

Sulfur and other emissions from burning fossil fuels are also a contributor to decreased visibility, as are natural and man-made hydrocarbons and ozone.

When averaged over long periods (one year or more) and large geographic scales (on the order of 1 million square kilometers), emissions and acid deposition appear to be related in a linear fashion. However, under smaller spatial and shorter time scales, emissions may not be linearly linked to deposition, and greater deposition is likely closer to an emitting source.

Relating deposition to impact cannot yet be predicted. Soil acidification is a natural process in humid regions. Cutting and burning forests and other disturbances can also trigger soil and watershed acidification processes. Natural weathering counteracts acidifying processes, though at varying rates under varying conditions at different sites.

In short, real impacts are occurring, but neither the precise role of acid precipitation nor source-to-receptor relationships can yet be defined.

B. What is Indicated?

Many other relationships regarding the causes, sources, extent, and effect of acid rain have been postulated, but not fully verified. Some of the following points, not all of which are common wisdom, show strong scientific validity. Prudence in protecting the environment would dictate consideration of these factors in national policymaking.

Acidity (low pH) dating back millennia has been observed in ice core samples from Antarctica, Greenland, and the Himalayas. Volcanic eruptions can create acid precipitation, and many historical eruptions have been dated through ice core samples. Acid deposition not directly correlated with eruptions may extend back as far as 350 or more years ago.

In recent years, natural sources of sulfur compounds have been a minor contributor (10 percent or so) to total observed sulfur loadings. The majority of sulfur compounds, therefore, arise from the combustion of fossil fuels.

The input of acids into natural environments is not uniform over the year. "Pulses" of acid inputs -- particularly after snowmelts -- have been observed, with many scientists claiming that these intense, short-duration events may have greater meaning than the observed pH levels of rainfall or annual averages.

The role of dry deposition of sulfates remains a wild card in the total deposition of acids in the environment. Monitoring and capture techniques remain to be fully perfected. Most models of acid deposition and scientific impact studies assume that roughly 50 percent of deposition occurs in dry form, but this assumption is based on mass-balance calculations and not empirical data. When combined with the non-linearity of emissions and deposition on small scales, it is apparent that setting "targets" for limiting deposition on a per acre or per hectare basis is problematic at best.

Not all fossil fuels may be created equal. It is known, for example, that primary sulfate emissions -- which are on average more likely to be transformed to acids than gaseous SO_2 -- are six to ten times higher for oil combustion than for coal. It is also known that oil contains higher levels of vanadium and nickel than does coal, and both elements are known catalysts for the acid transformation reaction.

Besides sulfur compounds, nitrogen oxides, chlorides, trace metals, and hydrocarbons have all been implicated in the acid transformation pathway. Trace metals may be especially worrisome. Not only have toxicity effects been demonstrated for many plants from the deposition of trace metals, but the mobilizing of trace metals in acidified environments may be the key cause of damage. Damage to fish and forests is as likely the result of aluminum toxicity, which can be released from acidified environments, than from acid rain _per se_.

Areas overlying granitic soils, which have little neutralizing or buffering capacity, are most prone to adverse impacts. A number of regions in North America therefore contain aquatic and forest systems sensitive to acidification. These regions are found throughout much of eastern Canada, New England, the Allegheny, Smoky and Rocky Mountains, and the northwest and northcentral United States.

Changing species composition or disruption of natural nutrient cycles which rely on microorganisms have not been documented for acid rain, but represent risks. If analogous to crop species, the majority of natural species would exhibit no effect on growth or yield due to exposure to acid rain, while for a minority of species, both positive and negative responses could occur.

Acid rain does not appear to have adverse human health effects. Though connections to Alzheimer's disease and methyl mercury poisoning have been posited, they are unverified, and alternative explanations are credible.

In short, many regions of the United States may be at risk from an incompletely understood set of environmental impacts. The impacts are not solely the result of acid precipitation, but may occur in conjunction with, or apart from, other mechanisms. Sulfuric compounds, nitrogen compounds, chloride, trace metals, and hydrocarbons are all involved.

Rather than defining the problem narrowly as one of SO_2 emissions and acid rain, the problem would be more effectively viewed as a complex of impacts resulting from emissions from fossil-fueled combustion and smelting metallic ores.

C. What Are the Key Areas of Disagreement?

Unfortunately, insufficient data exist to define the ecological risks posed by acid rain and the combusting of fossil fuels. These risks relate to the extent, rate, and reversibility of impacts. Since the lack of data allows only speculation, these risks are subject to broad disagreement.

As to extent of impact, lakes devoid of fish and reduced forest yields have been demonstrated. For some of the adversely affected lakes, soil acidification which may occur after forest clearcutting and burning in the watershed remains a credible and logical explanation. For some of the forest effects, such as the dieback of pines in the San Bernardino Forest in California, sulfur emissions are clearly not implicated, and the problem may be more one of ozone than acid precipitation. Thus, while adverse impacts are being documented, the role of acid rain per se remains unclear.

As to rate of impact, historical data is insufficient to draw long-term trend lines for rainfall acidity. Short-term trends (20 years or less) indicate rainfall pH may have been increasing (becoming more alkaline) in the Northeast, and becoming more acidic in the South and West. Without defensible trend lines in the pH of rainfall, it is difficult to gauge the urgency of action. Do we need to act now or can we afford to wait five, ten, or twenty years?

Finally, insofar as there are adverse impacts, are they short term and reversible or long term and irreversible? If irreversible, action would need to be taken now.

Each of these contentious issues carries with it major cost implications. National efforts to lessen the potential damage from acid rain may cost vast sums of money, approaching $50 billion to $80 billion over the lifetime of various programs now before the Congress.

D. **What Can We Conclude?**

APPA believes that prudent action to control acid rain is justified now. However, given the large scientific uncertainties and potentially large costs, APPA believes that a cost-effective and flexible strategy must be developed that acknowledges these factors:

- All fossil-fuel combustion and metallic ores smelting are likely to contribute to impacts;
- Both mobile and stationary sources are implicated;
- Though emitted at different levels and rates, and though not equally controllable or equally controllable at tolerable costs, sulfur oxides, nitrogen oxides, trace metals, hydrocarbons, and chlorides are implicated; and
- The potential for adverse impacts is not confined to the Adirondacks or the eastern U.S.

While APPA believes action is warranted now, the actions taken should be moderate in scope. Premature commitment to a massive emission reduction program -- coupled with costly requirements for use of continuous emission reduction technologies -- may prove to be an expensive mistake, as was mandating the use of tall stacks in the Clean Air Act of 1970. As additional knowledge is developed, targeting of emission reductions to source categories, individual sources, or certain fossil fuels may be possible. In this way, the nation would be assured of receiving the maximum reduction in environmental threat for the least possible expenditure.

II. IMPLICATIONS FOR NATIONAL ACID RAIN CONTROL LEGISLATION

As consensus has grown around the need for meaningful acid rain controls, controversy has emerged as to the acceptable mechanisms for instituting and paying for these controls. APPA believes -- based on the scientific indications described above, as well as on support from our members in all regions of the country -- that a reasonable balance of the consumer interest in a clean environment with a need for reliable electrical power at a reasonable cost requires consideration of the following key principles in acceptable acid rain legislation:

1. There should be a nationwide funding mechanism based on SO_2 and NO_x taxes on emissions from all fossil-fueled sources.
2. Funds raised should be applied to the most cost-effective emission reduction measures.
3. Emission reductions should be based on a "pay as you go" approach.
4. The reduction program should have two phases, with implementation of the second phase based on an affirmative decision by the Congress.
5. Emission reduction goals should adequately allow for future growth, and emission caps or "offset" requirements should be rejected.

Each of these points will be addressed in turn.

1. **National Emissions Tax**

We believe a nationwide funding mechanism for acid rain controls is essential. Acid precipitation is a national problem, and it needs a national solution. Areas throughout the United States may be sensitive to effects from acid deposition. A nationwide approach avoids drawing arbitrary boundary lines between those who are and who are not liable for the costs of control.

We are all aware that much of the cleanup will be done in the Midwest, which, without a national financing scheme, could suffer economic disruption unacceptable to the nation as a whole. Any program which increases utility rates significantly can impair the ability of energy-intensive industries to compete, either domestically or internationally. The energy-intensive industries located in the Midwest include steel, autos, chemicals, and aluminum. For these industries, rate increases may mean slower recovery from recession and higher job losses.

APPA believes the taxing mechanism should be an emissions tax applied to SO_2 and NO_x emissions from all mobile and stationary fossil-fueled sources for which an emissions tax is feasible. Sources specifically include cars and trucks, smelters, industrial boilers, industrial processes, and utility boilers. "Feasibility" should be an administrative determination.

An emissions tax is superior to other funding mechanisms because:

- Insofar as acid rain is a problem, it is a problem of emissions.
- An emissions tax credits past cleanup. States like Michigan and Minnesota, which have made large emissions cuts, pay less because they emit less.
- It gives incentives for future cleanup. Some sources will reduce emissions without federally mandated reduction requirements to avoid the tax.
- It is regionally equitable. States with low emissions, like many in the West, pay only their fair share.

- It offers ancillary benefits like improved visibility. The key point is that, irrespective of the sensitivity of a particular region to acid rain, an emissions tax offers at least some measure of benefit to all.

- It is administratively workable. "Administrative difficulty" has been raised as an argument against emissions taxes. We think this issue is a red herring. The practicality of using emission taxes to fund pollution reduction measures is demonstrated by their successful use today in Japan, the Netherlands, and Norway. Pollution charges are successfully applied in other countries to water, noise, and solid waste as well. Members of the committee may wish to examine the description and analysis of foreign systems in successful use today for administering SO_2 emission charges, as well as charges on other forms of pollution, provided in the publication "Pollution Charges in Practice" of the Organization for Economic Cooperation and Development (1980). It is clear that in practice pollution charges are feasible, economically efficient, and commonly conceived to be equitable.

2. The Fund Should Pay for the Most Cost-Effective Emission Reduction Measures

APPA believes that monies raised through the emissions tax should be used to fund the most cost-effective verifiable emission reduction measures available. Such measures for SO_2 reductions specifically include fuel switching, fuels pretreatment, flue-gas desulfurization ("scrubber") systems, and other measures now under development whose performance can be verified over the course of the program.

Estimates for the cost savings of a least-cost approach as opposed to an approach mandating "continuous emission reduction technologies," or scrubbers, have been conservatively placed at 25 percent. Given present scientific uncertainties in source-to-receptor relationships for acid rain, and the absolute lack of evidence that SO_2 emissions reduced through scrubbing offer any benefits over other SO_2 reduction measures, solely mandating continuous emission reduction technologies should be rejected on simple economic grounds.

APPA acknowledges that certain emission reduction measures, specifically fuel switching, are politically controversial on economic, not environmental, grounds. However, even if fuel switching is legislatively limited, a least-cost standard is valid. The program's cost-effectiveness over other approaches would be lessened, but not lost. Even assuming that large unemployment impacts from excessive fuel-switching would occur and are unacceptable, such impacts should be examined carefully to minimize extra costs. We believe that analysis will suggest measures other than prohibition of fuel-switching -- including minimum limitations on fuel switching, or adoption in defined cases of retraining and relocation programs -- which may adequately deal with case-specific objections where they arise.

In deciding cost-effectiveness, APPA urges that site-specific factors limiting the practicability of retrofit, operation and maintenance costs, capital costs, relative fuel costs, and the useful remaining lifetime of facilities be considered. In essence, this recommendation suggests a life-cycle costing basis for evaluating emission reduction measures.

Because the objective of an acid rain control program is to lessen damage to sensitive ecosystems, there may be instances where cost-effectiveness criteria may need to be waived in order to target emission reductions to source areas that are demonstrably impacting selected receptor areas. However, since present science does not yet allow these determinations to be made, provisions for targeted reductions do not appear to be warranted at this time. If and when such determinations are made, APPA would support a targeted reduction program.

3. A "Pay As You Go" Approach

APPA urges that legislation incorporate a "pay as you go" or "clean as you pay" strategy. This recommendation means that the financing program should remain in effect until emission reduction goals are met, and that sources required to reduce emissions at the end of the program would be assured of having the same financing support as those required to make reductions at the beginning of the program. Programs based on unrealistic promises backed by inadequate funding will be accepted reluctantly, if at all, by consumers and industry alike.

4. A Phased Reduction Program

APPA supports a two-phased reduction program, with the continuance of the second phase contingent upon affirmative action by the Congress. Given the substantial scientific uncertainties that presently exist, the very large costs associated with any reduction program, and the likelihood that improved information upon which to base decisions will be developed in the future, this recommendation assures that mid-course corrections can be made in the program if necessary.

5. Emission Reduction Goals Must Allow for Future Growth

APPA urges that any emission reduction goals set in acid rain control legislation reject "caps" or requirements for "offsets" which would act to preclude future industrial growth.

Without appropriately allowing for growth from new sources, the overall emission reductions required are understated. Furthermore, new capacity is subject to a "double whammy:" first, by paying for control technologies to meet new source performance standards, and, second, by paying for "offsets" from existing sources for the emissions that remain after NSPS control. These offsets would be some of the most costly and difficult to obtain, since the easier emission reductions at existing sources would have already been claimed to meet the emission reduction goals of the acid rain control program.

We also recommend that legislation include the following provisions:

- Calculation of emissions taxes on the basis of actual rather than allowable emissions; and
- Provision to allow electric utilities discretion to include their contributions to the emissions tax as a line item on utility bills.

Finally, APPA believes adequate monitoring and continued research should be a major provision in any acceptable acid rain legislation. Our recommendations in this area are detailed in the next section.

III. **REMAINING RESEARCH AND DEVELOPMENT NEEDS**

Mr. Chairman, APPA members are willing to pay their fair share to reduce acid rain and to protect the environment. APPA believes that Congress should recognize the large costs which electric utilities and consumers will bear by assuring that adequate funding is provided to reduce the scientific uncertainties regarding acid rain and to continue R&D support for efficient, clean, and economic fossil fuel technologies.

For mid-course review and correction to be possible, additional information on the effects of measures taken must be available to ensure that the national resources expended on acid rain controls are in fact achieving their objectives. APPA urges strongly that an adequate monitoring program be established which could demonstrate a decrease in the impact of acid rain or in the acidity of deposition to justify the substantial monies expended.

In addition, APPA strongly supports the acid rain research efforts presently underway, and urges stepped up efforts in a number of key areas of scientific uncertainty. Foremost among these areas are:

- the role of natural acidification in disturbed habitats;
- the role of local sources vs. long distance sources, as that may be clarified by determining the relative contributions to acid rain of different fossil fuels, particularly in order to answer the critical

question whether oil combustion is more likely to be harmful than coal combustion; and

- the rate at which damage from acid rain is occurring, a determination which would be assisted by more extensive ice core sampling and controlled field experiments.

Finally, APPA endorses the recommendations of the National Academy of Sciences panel on "Research Needs" in its 1983 report. One of the unfortunate outcomes of the debate concerning "linearity" versus "non-linearity" that was generated by the 1983 NAS report was that its chapter on "Research Needs" was largely overlooked. Besides providing a reasonable and doable set of guidelines for further research, careful study of the research recommendations acts to place confidence limits on the recommendations in the main body of the NAS report. In fact, the chapter on research needs conveys the impression that the gaps are much larger than the certainties in the science of atmospheric transformation and deposition of acid rain.

In terms of fossil fuel R&D, APPA urges continued support by this committee for the development of clean and efficient alternatives for the future. Specifically, APPA urges research and development activities pertaining to:

1. Coal preparation;
2. Specification fuels (clean, usable coal-derived fuels);
3. Precombustion cleanup;
4. Postcombustion cleanup;
5. Utilization processes
   a. Improved direct combustion;
   b. Atmospheric and pressurized fluidized bed combustion;
   c. Other (in situ) pollution control technologies;
   d. Fuel cells;
   e. Diesel engines;
   f. Gas turbines, using clean fuels from coal;

   g. Heat recovery technologies (cogeneration, district heating and cooling, etc.); and
   h. Magnetohydrodynamics;

6. Instrumentation and control (for improved efficiency of operation); and

7. Solids (principally ash) handling, use, or disposal.

These R&D initiatives would help ensure continued declining costs over time for sources which must comply with emission reduction measures. Such R&D dovetails with the APPA recommendation for pursuing least-cost reduction measures in the design of a legislative package.

Furthermore, under a least-cost approach, emission reductions which occur later in a control program would cost inherently more than reductions which occur at the beginning of the program. These later, higher marginal cost controls could benefit particularly from a strong R&D effort in pollution control. Strong R&D support will help ensure that the biggest bang for the buck is being achieved over the full time period of a control program.

IV. CONCLUSIONS

To date, the American Public Power Association is the only national electric utility organization to embrace a comprehensive program for dealing with acid rain control legislation. Significantly, though, a number of utilities and state and regional utility associations have followed APPA's lead and endorsed similar programs. Electric Light and Power magazine, a major national electric utility periodical, has editorially endorsed the APPA approach. We believe that our proposals point the way to effective, workable, and meaningful grounds for agreement in dealing with one of the most difficult environmental issues of our times.

We urge the committee to study our Special Task Force's Policy Report, attached to this statement, in detail. We believe that our joint responsibilities to both consumers and the electric utility industry alike have allowed us to craft a position that transcends parochial interests. Our actions demonstrate that fair and equitable acid rain legislation can be crafted that meets the needs of our nation's various regions.

As a final note, Mr. Chairman, APPA would like to reiterate that what we are proposing is a framework and set of goals for legislation. Because of the complexity inherent in any approach to control acid rain, APPA hopes that the Congress will see fit to establish the targets and approach to be followed in acid rain legislation, but will leave detailed implementation to the regulatory process, where it can be handled most appropriately.

Mr. Chairman, I thank you and the committee for the opportunity to present APPA's views on the status of scientific knowledge regarding acid precipitation and its implications for national control legislation and research and development.

Attachment A

POLICY REPORT
OF
APPA SPECIAL TASK FORCE ON ACID RAIN

August, 1983

I. Introduction

At the request of APPA President Robert McKinney, a 25-member Special Task Force on Acid Rain was convened in Washington, D.C., on August 10 and 11, 1983. The purpose of the Task Force is to provide interim policy guidance to APPA staff, within the framework of the Association's acid rain resolution approved on May 3, 1983. This guidance is needed to specify the positions APPA should take on proposals relating to such issues as national taxes or fees to provide a cleanup fund, and how burdens should be spread across specific regions, industries, ratepayers, or consumers. APPA's policy resolution establishes general criteria by which legislation should be evaluated, but does not address these crucial issues. Because this is a national issue potentially affecting all utilities, the Task Force has a broad geographic base, including utilities which are wholesale purchasers as well as generators of electricity. Most members of the Task Force are members of the Legislative and Resolutions Committee.

The action of the Task Force serves as interim policy subject to review or modification at the next meeting of the Legislative and Resolutions Committee in February, 1984.

II. General Conclusions: The Necessity to Support Effective and Equitable Acid Rain Control Legislation

There is now a substantial likelihood that Congress will enact legislation mandating sulfur dioxide (SO_2) emission reductions in the near future. Momentum for legislation has grown as a consequence of several developments of serious import.

These include: increasing public concern that acid precipitation resulting from fossil fuel combustion may be causing environmental damage; mounting congressional support for legislation; the recent publication of two new scientific reports which strengthen the case for action; and the Reagan Administration's anticipated endorsement of acid precipitation control legislation.

Public opinion polls indicate that an overwhelming majority of Americans favors stronger environmental protection laws, including acid precipitation control requirements. A majority of Americans indicates a willingness to pay the costs of such programs. Local public power systems share the concern of the communities they serve that the natural environment be protected.

As public concern has grown, so has congressional support for legislation. In the last Congress, legislation providing for an acid rain control program was approved by the Senate Environment and Public Works Committee. In the

98th Congress, proposals have proliferated and gained substantial cosponsorship. Most of these proposals target electric utilities almost exclusively for emission reductions; target electric consumers to pay the costs; and contain no consideration of cost-effectiveness in the control measures proposed.

Hearings are expected to begin in the House and Senate in the early fall, 1983. Predictions for the legislative timetable vary, but enactment in 1984 is widely agreed to be probable.

In June, 1983, the case for immediate action was bolstered by two scientific reports. A White House scientific "peer review" panel convened to assess the acid rain problem issued a statement of its preliminary findings, saying: "Recommendations based upon imperfect data run the risk of being in error; recommendations for inaction pending collection of all of the desirable data entail even greater risk of damage." Furthermore, the panel raised the specter of "irreversible" damage from acid rain.

At the same time, the National Academy of Sciences' National Research Council issued a report supporting a link between the level of sulfur dioxide and nitrogen oxide (NO_x) emissions and the level of acidity in precipitation. In the press release (though less clearly in the report), it was stated that "the relationship between [SO_2] emissions and [acid] deposition can be taken for practical purposes as essentially linear," meaning that most or all SO_2 is converted into sulfate-derived acids. While this statement may be challenged on scientific grounds, and inaccurately describes the conclusions of the text of the report, nevertheless the imprimatur of the National Academy of Sciences must be taken with the utmost seriousness. The statement of the White House scientific panel underscores the weight which the Academy's views must be accorded.

The Reagan Administration, which previously supported only accelerated acid rain research efforts, is now in the process of revising its position. The Administration is expected to propose legislation in early September which is likely to include substantial reductions in SO_2 emissions.

Thus, the acid rain debate now increasingly centers on how, not whether, to structure an acid rain control program. The Task Force believes that, if current predictions regarding the time frame within which legislation will be formulated are correct, public power systems have a vital opportunity now to participate in the design of legislation.

Acting upon that opportunity is made more urgent by the serious deficiencies which the Task Force believes most current bills contain. Public power systems have a responsibility to participate in the formulation of legislation to ensure that its provisions meet reasonable standards of effectiveness, economy, and equity within the framework of present scientific understanding.

APPA's policy resolution on acid rain control legislation sets these standards as criteria against which legislation should be evaluated. APPA's resolution also notes that many pending legislative proposals "would impose emission cuts exclusively on electric powerplants without regard to: other stationary or mobile source contributions; total cost; relative cost-effectiveness of different emission reduction measures; ascertainable benefits; and equitable distribution of cost burdens...."

If the present opportunity to participate in the design of legislation is foregone, then the program finally enacted may fail, by default, to meet the essential standards set out in Association policy.

Therefore, by unanimous vote on August 11, the Special Task Force on Acid Rain adopted a series of recommendations regarding acid precipitation control legislation as detailed in Part III of this report.

The Task Force has endeavored to ensure that the positions supported in this report meet the criteria for acid precipitation control legislation which are set out in the Association's policy resolution approved by the general membership on May 3, 1983. The positions of the Task Force are not intended to constitute a comprehensive legislative proposal. For example, the Task Force does not attempt to resolve such issues as the extent to which emissions should be reduced or the time frame within which such reductions should occur, although Task Force members concur that initial reductions should be moderate and the time frame adopted should not require exorbitant annual taxation levels. Instead, the positions are intended to serve as a set of coherent principles for legislation.

III. Recommendations for Acid Precipitation Control Legislation

The Task Force proposes 10 specific elements of a legislative program. These proposals and the rationale for their adoption follow:

1. *A nationwide sulfur dioxide and nitrogen oxide emissions tax should be applied to all fossil-fueled sources for which an emissions tax is feasible.*

This is the most far-reaching of the Task Force's recommendations. It specifies a taxing mechanism, its geographic applicability, the pollutants to be taxed, and the source categories to which the tax is to be applied.

The Task Force rejects schemes without financing (or "cost-sharing") mechanisms, as embodied in last year's Senate Environment and Public Works Committee acid rain proposal. There are a number of reasons to reject legislative approaches which do not contain financing mechanisms. They include the large uncertainties associated with the eventual capital requirements of an "open-ended cost" bill; the prospect of drastic impacts on the economies of several already distressed states, as well as upon individual utilities; the political unacceptability of such impacts; and the implicit, but unavoidable, assumption that long-range transport is the dominant mechanism leading to acid deposition.

Three cost-sharing schemes were investigated in detail:

- kWh tax;
- Btu tax;
- emissions tax.

One of the leading proposals being considered in Congress at the present time is the Sikorski/Waxman bill (H.R. 3400), which would impose a 1 mill per kilowatthour fee on all non-nuclear electric generation, including hydroelectric generation. Senator John Glenn (D-OH) has proposed a 3 mill per kilowatthour fee on fossil fuel generation in a 31-state region. While the Task Force recognizes the administrative simplicity of a kWh tax, it rejects an electricity tax because it unfairly targets utility customers to pay all control costs. Further, an electricity tax does not recognize or credit emission reductions already achieved by individual utilities and their ongoing costs to ratepayers; nor does it provide incentives for future cleanup. The problem is not the consumption of kilowatthours, but the emission of pollutants that can lead to acid precipitation.

A Btu tax -- either at point of sale or as a levy on energy inputs to boilers, industrial processes, or other combustion sources -- is disadvantageous for some of the same reasons: it neither credits emission reductions achieved nor gives incentives to reduce emissions. In addition, a Btu tax would account inadequately for emissions from nonferrous smelters -- where significant emissions result from sulfur in the ore and not in the fuel -- and would be administratively complex.

After detailed evaluation, the Task Force supports an emissions tax as the best available alternative: (1) it fairly apportions the tax liability to those sources contributing most to the precursors causing acid rain; (2) it credits past cleanup; and (3) it provides incentives for emissions reductions, since any reduction will reduce tax liability. An emissions tax best addresses the sources of acid rain in a manner which is economically efficient.

Though substantial attention has been given to regional application of the tax, the Task Force concurs that a nationwide tax is preferable. First, a regional tax may be unconstitutional (Article I, Section 8, of the U.S. Constitution states that all "Duties, Imposts and Excises shall be uniform throughout the United States."). Also, although the Task Force's consensus was that costs of cleanup should be borne by emitting sources insofar as reasonably possible, the Task Force appreciates that there is substantial political opposition to strict application of this principle and that the already economically distressed industrial Midwest could face unacceptable additional burdens.

Other facts as well support a nationwide approach. Foremost among these is scientific evidence that areas throughout the United States may be sensitive to effects from acid deposition, and that acid deposition has been documented in many states outside the Northeast. Finally, a nationwide approach avoids drawing arbitrary boundary lines between those who do and do not pay a tax.

The Task Force supports an emissions tax on both sulfur dioxides and nitrogen oxides. Tax applicability to both is based on the strong scientific evidence that both SO_2 and NO_x contribute to acid deposition.

The Task Force agrees with the scientific evidence that all fossil fuel combustion can create precursors to acid deposition, and therefore recommends that SO_2 and NO_x emissions from all fossil fuel sources should be liable to the tax so long as it is feasible. Source categories specifically include cars and trucks, smelters, industrial boilers, industrial processes, and utility boilers. The caveat, a test of "feasibility," is included to account for the potential difficulty of applying an emissions tax to many small stationary sources or to the nation's existing population of cars and trucks. Note, however, that all fossil fuel sources should be included in initial consideration for taxation, and should be excluded only if an emissions tax is shown to be infeasible to administer.

2. *The fund derived from the tax should be employed to finance verifiable emission reduction measures.*

Funds raised should be applied to measures (not merely "technologies" like scrubbers) which will reduce emissions in accordance with the reduction goals to be specified in legislation. The Task Force specifically recognizes the following SO_2 emission control measures: 1) fuel switching; 2) fuels pre-treatment, including physical coal cleaning, chemical coal cleaning, and oil desulfurization; 3) flue-gas desulfurization systems (scrubbers) on nonferrous smelters, industrial and utility boilers, and other industrial processes; and 4) any other emission reduction measure now under development whose performance can be verified during the term of the program. The Task Force considered a recommendation to set aside a portion of the fund for the demonstration of advanced pollution control or energy-efficient technologies, but chose not to adopt a position because support for demonstration of such technologies may best be considered in EPA or DOE appropriations.

3. *The purchase of emission reduction measures should not be mandated in excess of the monies available in the fund.*

Sometimes described as a "clean as you pay" strategy, this requirement would ensure that legislation promises no greater reduction in emissions than can realistically be achieved by the fund. By keying emission reductions to the funds available, sources required to reduce emissions at the end of the program are assured of having the same financing support as sources required to reduce emissions at the beginning of the program. This provision would keep the legislation honest. In practical terms, this recommendation means that the financing program would remain in effect until emission reduction goals are met, and would not expire at an arbitrary date. Also, this provision would require that the cost of the program be acknowledged at the program's inception, thereby setting a cap in any given year on the national expenditures devoted to address the acid rain problem.

4. *The fund should be applied to the capital costs of the control measures chosen.*

Under various financing schemes, either capital costs or operation and maintenance costs -- or percentages of both -- have been considered for eligibility to receive funding. Because of the potential difficulties in raising the large amounts of capital which may be required for individual sources mandated for control measures, the Task Force supports their application to capital costs only. In instances where scrubbers may be mandated, capital costs are roughly equivalent to operation and maintenance costs over the lifetime of a facility. While the Task Force is fully aware that operation and maintenance costs could be a significant cost burden for those mandated to install controls -- particularly for many large sources in the industrial Midwest -- the Task Force also recognizes that this cost burden would be lessened somewhat by the decrease in the emissions tax which would accompany an emissions reduction program at individual facilities.

In those instances where fuel pre-treatment may be the mandated emission control measure, the Task Force supports the use of monies in the fund for installing additional capacity for treatment as necessary. Fuel pre-treatment specifically includes coal cleaning and oil desulfurization.

Fuel switching often entails capital costs. For example, precipitator redesign or the use of baghouses may be required when switching to low sulfur coal. Such costs would obviously be covered under the fund. When fuel switching does not involve capital costs, no monies would be made available from the fund, though any higher costs associated with using premium low sulfur fuels would be somewhat compensated by lower emission tax liability.

5. *Emission reduction measures for stationary sources should be selected in order of cost-effectiveness, including consideration of the remaining useful life of facilities, with allowance made for administrative consideration of the likelihood of reducing impact in sensitive receptor areas.*

Since the Task Force lacks expertise in emission reduction measures which may be feasible for mobile sources such as cars and trucks, the Task Force is silent on the question of mobile source control. For stationary sources, however, the Task Force emphatically supports pursuit of control measures which give the "biggest bang for the buck" -- achieve the largest possible reductions at the lowest possible cost. Not only is this cost-effectiveness criterion the most economically efficient approach, but, in the absence of definitive identification of source-to-receptor relationships, it best responds to scientific uncertainties.

Though not specifically addressed in this recommendation, the consensus of the Task Force is that both SO_2 and NO_x emission reductions should be eligible for financing, but that NO_x reductions should be discretionary and creditable to overall SO_2 emission reduction goals. Thus, for example, lowering excess air in boilers to reduce NO_x would not be mandated, but individual sources could receive funding to install low NO_x burners should they be found cost-effective.

The Task Force urges that cost-effectiveness judgments on control measures weigh: the site-specific factors limiting the practicability of retrofit of control measures; operation and maintenance costs; capital costs; and the useful remaining lifetime of the facility receiving control. In essence, this clause stipulates application of a life-cycle method of costing to individual facilities.

In many cases, fuel switching may be the most cost-effective control measure. Task Force members are unanimous in supporting fuel switching as an option to reduce emissions. The Task Force is aware, however, that political, not economic, parameters may eliminate fuel switching as a permissible control option.

The Task Force notes that application of a cost-effectiveness standard would benefit the nation with costs at least 25 percent lower than those entailed by approaches which rely on "continuous emission reduction technologies" (that is, scrubbers).

Consideration of the "likelihood of reducing impact in sensitive receptor areas" provides for some form of targeting emission reductions to either particular regions or to particular emission sources should scientific evidence so warrant.

6. *The emission reduction program should be divided into two phases, with the second phase to take effect contingent upon affirmative congressional action, including findings that the program is achieving its objectives.*

This proposal takes account of three facts central to the acid rain dilemma. First, present scientific data have yet to determine adequately the extent of damage from acid rain, the rate at which that damage is occurring, and the individual sources that may be causing such damage. Second, legislation to address acid rain is likely to impose a formidable cost burden on the nation. And third, scientific evidence in the years to come may allow fine-tuning of the emission reduction program. By requiring affirmative action by the Congress to proceed with a second phase, the practical result is to allow for mid-course review and correction. Also, by setting emission reduction goals in two phases, a greater incentive results to reduce the cheapest emissions first, thereby bolstering a cost-effectiveness approach.

7. *The program enacted should provide for adequate monitoring and continued research to gauge the effectiveness of the emission reduction program.*

Obviously, for mid-course review and correction to be possible, additional information on the effects of measures taken must be available. This recommendation assures that the national resources expended on acid rain controls are in fact achieving their objectives. The Task Force urges strongly that an adequate monitoring program be established which could demonstrate a decrease in the impact of acid rain or in the acidity of deposition to justify the substantial monies expended.

In addition, the Task Force strongly supports the acid rain research efforts presently underway, and urges stepped up efforts in a number of key areas of scientific uncertainty. Foremost among these areas is the role of natural acidification from humic or other organic acids in disturbed habitats. The Task Force also believes that the present debate over the role of local sources vs. long-distance sources needs to be refined in the context of the contributions to acid rain from burning different fossil fuels; specifically, does oil combustion have a greater likelihood of adverse impact than coal combustion? Finally, the Task Force believes greater attention should be paid to the rate at which damage from acid rain is occurring, determinations which would be assisted by more extensive ice-core sampling and controlled field experiments. These recommendations are in addition to the excellent recommendations for additional research made in the recent National Academy of Sciences report.

8. *Emission taxes on stationary sources should be based on actual rather than allowable emissions.*

Many industrial and utility sources do not operate full-time. For these sources, tax liability should reflect their actual contribution to the problem -- that is, actual emissions.

The Task Force addresses this recommendation only to the case of stationary sources. It may be necessary and practical to tax mobile sources on expected -- rather than actual -- emissions. For example, new automobiles could be taxed at point of sale based on measured emissions per mile over their expected lifetime.

9. *No requirements for offsets for new facilities should be included in the emission reduction program.*

Like the policy above which stipulates that control funds expended should not exceed the emission tax collected, this provision would keep legislation honest. For example, emission reduction goals which do not account for future growth underestimate the total reductions required. When such underestimates occur, new sources are forced to find additional emission reductions from existing sources in order not to exceed emission ceilings. Yet, the existing sources from which these "offsets" must be obtained may be the very same sources that are being required to reduce emissions under the general provisions of the reduction program. Thus, not only would offsets be scarce and difficult to obtain, but they would also be extremely expensive. Under this scenario, it is also likely that small sources would be placed at a competitive disadvantage in buying offsets.

Therefore, any emission reduction goals stipulated in legislation should properly account for future growth. Furthermore, the Task Force is skeptical about the viability of the emissions trading or offset approaches that have been advanced in acid rain proposals.

10. *Electric utilities should have discretion to include their contribution to the emissions tax as a line item on utility bills.*

Given the large overall costs, and disproportionately larger costs for specific utilities, of an emissions reduction program, the Task Force supports discretion to utilities to specify to their consumers why electric rates may be rising.

Respectfully submitted,

Dan Waters
Los Angeles Department
of Water and Power
Chairman, APPA Special Task Force on Acid Rain

August 19, 1983

Attachment B

FEDERAL ACID RAIN CONTROL LEGISLATION

WHEREAS, there is now growing public, scientific, and congressional concern that acid precipitation resulting from fossil fuel combustion may cause environmental damage, and

WHEREAS, although the causes, sources, extent, and effect of acid precipitation are still subject to controversy within the scientific community, a significant and influential body of scientific opinion now subscribes to the view that the risk of environmental damage from inaction outweighs the risk of error from action based upon imperfect data, and

WHEREAS, available data show that all fossil fuel combustion emissions, from both local and distant sources, are apparently implicated as causes of acid precipitation, including nitrogen oxides and trace metals, and

WHEREAS, congressional support for action to reduce acid precipitation continues to build, but many pending legislative proposals, including legislation approved by the Senate Environment and Public Works Committee in the 97th Congress, would impose virtually all cost burdens for emission cuts on electric utilities and their consumers, without regard to: other stationary or mobile source contributions; total cost; the relative cost-effectiveness of different emission reduction measures; and equitable distribution of cost burdens, and

WHEREAS, in the House of Representatives, H.R. 3400, sponsored by Representatives Henry Waxman (D-CA), Gerry Sikorski (D-MN), and 106 cosponsors, would finance emission cuts by the 50 largest powerplant sources of emissions through a nationwide kilowatthour tax on electricity;

(OVER)

NOW, THEREFORE, BE IT RESOLVED: that the American Public Power Association supports the enactment of acid rain control legislation which meets reasonable standards of effectiveness, economy, and equity within the framework of present scientific understanding, and

BE IT FURTHER RESOLVED: that APPA believes that the elements of such a program should incorporate the following principles:

- A nationwide sulfur dioxide and nitrogen oxide emissions tax should be applied to all fossil-fueled sources for which an emissions tax is feasible;
- The funds derived from the tax should be employed to finance verifiable emission reduction measures;
- The purchase of emission reduction measures should not be mandated in excess of the monies available in the fund;
- The funds should be applied to the capital costs of the control measures chosen;
- Emission reduction measures for stationary sources should be selected in order of cost-effectiveness, including consideration of the remaining useful life of facilities, with allowance made for administrative consideration of the likelihood of reducing impact in sensitive receptor areas;
- The emission reduction program should be divided into two phases, with the second phase to take effect contingent upon affirmative congressional action, including findings that the program is achieving its objectives;
- The program enacted should provide for adequate monitoring and continued research to gauge the effectiveness of the emission reduction program;
- Emission taxes on stationary sources should be based on actual rather than allowable emissions;
- No requirements for offsets for new facilities should be included in the emission reduction program;
- Electric utilities should have discretion to include their contribution to the emissions tax as a line item on utility bills,

and

BE IT FURTHER RESOLVED: that in no event should the program, or any federal government program, be financed through a nationwide kilowatthour tax on electricity.

-- Adopted by the Legislative and Resolutions Committee of the American Public Power Association February 8, 1984, in Washington, D.C.

Attachment C

CLEAN AIR ACT REAUTHORIZATION
(Revision of 1983 Resolution)

WHEREAS, local publicly owned utilities are dedicated to the welfare of the communities they serve and share the concern of the public and government for a clean environment, and

WHEREAS, the purpose of the Clean Air Act is to protect air quality by establishing national standards of performance for new sources of air pollution and to enhance air quality by attainment and maintenance of national ambient air quality standards established to promote the public health and welfare and productive capacity of the nation's population and resources, and

WHEREAS, the intent of the Clean Air Act has in certain respects not been clearly reflected in the statutory requirements and in regulations promulgated to enforce it, and

WHEREAS, a special Task Force of the Association has conducted a thorough analysis of the Clean Air Act and has made specific recommendations for improvement of the statute;

NOW, THEREFORE, BE IT RESOLVED: that the American Public Power Association endorses the following policy positions on reauthorization of the Clean Air Act as recommended by the Clean Air Act Task Force:

1. APPA endorses the Act's existing requirement that National Ambient Air Quality Standards to protect health and welfare be set with an adequate margin of safety;
2. Prevention of Significant Deterioration (PSD) provisions should be revised so that (a) proven Best Available Control Technology (BACT) is used as the controlling technology, (b) Class III increments are repealed, (c) Class II increments are repealed or simplified,

(OVER)

(d) Class I short-term increments are repealed, (e) fugitive emissions are excluded from calculations of increment consumption, and (f) PSD permits remain in effect so long as the permit holder is committed to construction. These changes would reduce the costly complexity inherent in the existing PSD program while protecting air quality.

3. The Act should be clarified so that "integral vistas" are not regulated through inclusion in the visibility protection requirements. Congress excluded "buffer zones" from the visibility program. The Environmental Protection Agency's use of "integral vistas" as a means of avoiding that Congressional ban should be corrected. States should be given the option of vetoing retrofits if they are determined not to be in the public interest.
4. The Act's deadlines for attainment of the National Ambient Air Quality Standards (NAAQS) should include provision for such extensions as are necessary for areas unable to meet ambient standards by the current statutory deadline. The statutory attainment dates cannot be met in many areas despite application of reasonable control measures. In addition, to target the Act's sanctions appropriately, nonattainment status should be defined in terms of areas identified by actual pollutant concentrations, not by political boundaries. Fugitive dust should not count toward determinations of attainment status, although sources should be required to use necessary controls.
5. New Source Performance Standards (NSPS) and Best Available Control Technology (BACT) should be considered equivalent where NSPS has been established, with BACT applied as the controlling standard elsewhere.

(MORE)

Lowest Achievable Emission Rate (LAER) requirements should be repealed. LAER, BACT, and NSPS have in most cases imposed essentially identical control technologies, forcing a needless duplication of effort in the review process. In addition, the percentage reduction requirements for new powerplant sulfur emission reductions should be repealed, and a maximum sulfur emission rate of 1.2 lbs./MMBtu should be applied uniformly.

6. In determining New Source Performance Standards, adequate consideration should be given to size distinctions within categories of new sources where economies of scale exist in pollution reduction measures.
7. Modifications of existing stationary sources should not be liable to New Source Performance Standard review unless the modification results in a significant increase over allowable emissions.
8. The innovative technology waiver of New Source Performance Standards should be modified to: (a) give states the authority to grant waivers subject to Federal veto, (b) allow waivers for technologies that may not be able to achieve NSPS emission reductions, but which represent a desirable balance of economic, energy, and emission reduction considerations, (c) grant permanent waivers to technologies that do not meet design expectations, and (d) promote the further development of promising technologies.
9. Construction or modification of stationary sources should be allowed in nonattainment areas when the sources meet applicable standards and provisions are made for lower overall emissions than before the construction or modification commenced.

(OVER)

10. Requirements for State Implementation Plans (SIP) should be simplified so that (a) state authority is increased, (b) discretionary changes, including short-term variances, are allowed, and (c) EPA approvals are expedited by setting time limits for the Administrator to act. These changes will result in the SIP's being truly state plans, and would reduce the burdensome process of near-total EPA review of each SIP change and modification.
11. The Act's present requirements for listing and setting emissions standards for hazardous air pollutants should be retained. Recent legislative proposals listing suspected pollutants by statute and requiring emissions standards unless the Environmental Protection Agency acts affirmatively to de-list such substances would result in costly controls on substances for which no reliable scientific justification exists.
12. Requirements for the use of computer modeling should be redefined so that (a) modeling is utilized only when its predictive value meets a specified, acceptable level of accuracy, and (b) "worst case" increment modeling is limited. Computer modeling of air pollution effects is a very inexact science, and cannot detect low pollutant concentrations within stringent short-term PSD increments.
13. The Act should give discretion to EPA and the states in the assessment of noncompliance penalties.

-- Adopted by the Legislative and Resolutions Committee of the American Public Power Association February 8, 1984, in Washington, D.C.

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United States Senate
COMMITTEE ON
ENERGY AND NATURAL RESOURCES
WASHINGTON, D.C. 20510

May 10, 1984

Mr. Michael Bergman
Staff Scientist
American Public Power Association
2301 M Street, N.W.
Washington, D.C. 20037

Dear Mr. Bergman:

On behalf of the Committee on Energy and Natural Resources, I wish to express its appreciation for your contribution to its April 30 hearing on the implementation of the Acid Precipitation Act of 1980.

In connection with your testimony, enclosed are questions on which we would appreciate your answers for the record. Your response by close of business Friday, May 25, 1984, would be appreciated. Any inquiries regarding this request should be directed to the attention of Richard D. Grundy, Professional Staff Member, at 224-2564.

Sincerely,

James A. McClure

James A. McClure
Chairman

JAM:rgbb

Enclosure

Questions Submitted to Mr. Michael Bergman by the Committee on Energy and Natural Resources

on behalf of Senator Ford

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

What percentage of the Nation's electric power is generated by APPA members? What proportion of that is coal-fired? How much of that is east of the Mississippi River and would be subject to S. 768?

Answers to

Questions Submitted to Mr. Michael Bergman
Staff Scientist
American Public Power Association

From
Committee on Energy and Natural Resources

Hearing on Acid Rain
April 30, 1984

AMERICAN PUBLIC POWER ASSOCIATION

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Seminole Electric Cooperative
Tampa, Florida
ROBERT C. YOUNG
Burlington, Vermont

May 25, 1984

The Honorable James A. McClure
Chairman, Committee on Energy
  and Natural Resources
361 Senate Dirksen Office Building
Washington, D.C. 20510

ATTN: Richard D. Grundy

Dear Senator McClure:

Please find enclosed APPA's response to the written questions submitted on the basis of my testimony on April 30 before the Committee on Energy and Natural Resources on the "State of Scientific Knowledge on Acid Precipitation and Its Legislative and Regulatory Implications."

If APPA may be of further assistance, please do not hesitate to contact us.

Sincerely,

Michael K. Bergman

Michael K. Bergman
Staff Scientist

Enclosure
MKB/mjm

Questions Submitted to Mr. Michael Bergman
by the Committee on Energy and Natural Resources

on behalf of Senator Ford

Oversight Hearing on Implementation of the Acid Precipitation Act of 1980

What percentage of the Nation's electric power is generated by APPA members? What proportion of that is coal-fired? How much of that is east of the Mississippi River and would be subject to S. 768?

In 1982, public power systems generated 221.4 billion kilowatt-hours, or approximately 9.8 percent of the total electricity generated in the United States. Of that amount, approximately 35.8 percent, or 79.4 billion kilowatt-hours, is coal-fired. One-third of that amount, or 26.2 billion kilowatt-hours, is generated in the 31-state acid precipitation control region subject to S. 768.

Of course, we anticipate that non-generating systems in the 31-state acid precipitation control region which purchase power at wholesale will, like all consumers, pay their proportionate share of their wholesaler's control costs. Thus, under S. 768, total cost liability for public power systems which purchase at wholesale as well as generate would be considerably higher than liability calculated on coal-fired public power systems alone.

More importantly, under APPA's recommended national emissions tax for acid precipitation which is applied to all fossil-fuel sources, public power systems would be liable to taxation and control requirements for electricity generation totalling 146.7 billion kilowatt-hours, over five times the generation directly subject to S. 768.

Senator WARNER. Mr. Wilson.

STATEMENT OF JAMES C. WILSON, PRESIDENT, ROCKY MOUNTAIN ENERGY CO., ON BEHALF OF THE ALLIANCE FOR CLEAN ENERGY

Mr. WILSON. I'm here today representing the Alliance for Clean Energy. I am president of the Rocky Mountain Energy Co. It's a coalition of some 30 organizations, a number of which are involved in various aspects of the coal business, some of which are coal consumers, and others have varying degrees of consumer involvement interest.

Senator WARNER. We'll put your entire statement in the record. If you would just be kind enough to touch on the points you think have not been covered adequately today.

Mr. WILSON. There are three points that I would like to briefly summarize right now, Senator, including a brief recitation of the ACE position on the overall issue, results of certain studies that we have recently concluded, just the key points of those results, and then to relate the results of those studies and our view of the characteristics of appropriate legislation to the express need for more research in this area.

On research first. ACE, none of its members, nor the organization as a whole holds itself out as experts on this difficult scientific problem. And we have formed no judgment, scientific judgments. However, we have been impressed by the conclusions drawn by a number of prestigious scientific organizations on this subject.

And recognizing that these organizations have, on balance, concluded that while there is no final proof of the cause-effect relationship between SO_2 emissions and acid precipitation, nevertheless, on balance there seems to be sufficient evidence to warrant moving ahead on a program to reduce the acid precipitation.

I think we have been impressed with those studies and the implication of those studies and, as a matter of fact, that really is what brought this group of companies together to form ACE. It was recognition that it appeared that some legislation was inevitable, or highly likely.

And we undertood the mission of helping to assure that that legislation took on the most positive and constructive form.

We have been influenced further, I think, in that respect by noting the mood of Congress, which seemed to be heading in the direction of legislation. And at the same time, recognizing that respected public opinion polls are indicating that the American public favors some form of legislation on about a 3-to-1 basis.

On the kind of legislation that ACE has favored: First, we are looking for a feasible legislation; second, legislation that has characteristics of flexibility, flexibility with respect to freedom of choice, with respect to being open to future technology and the benefit of that, with respect to the timing of the implementation of any program; and, of course, legislation that produces a program that is least costly.

For us there are two bills now, the Senate bill 768, and the newly introduced Chaney-Udall bill, tend to employ or embrace the characteristics that ACE has favored.

Now, this kind of conclusion is supported by a number of inquiries we have made, rather elaborate or sophisticated studies, trying to assess the ultimate economic implications of some of these studies.

And by and large, the conclusion of those has been that freedom of choice is a vastly more efficient and effective means of approaching this problem.

In very recent time, we concluded an additional study working with a respected Washington consulting firm, ICF, done a number of energy policy studies, particularly those affecting utilities, and had three particular objectives in this latest work:

1. To test the feasibility of early reductions in SO_2 emissions.
2. The response of the cost of reductions to higher levels of—target levels of reduction.

And finally, the value of any phasing reductions.

Now briefly, those findings are with respect to, say the feasibility of a 1990 target, that free choice approach would permit reduction, effective reduction of about 5 million tons over that period. Whereas, a mandated scrubbing approach would permit the reduction of only half that quantity.

So that the so-called Waxman bill in the House isn't even a feasible approach to this problem.

Second, with respect to the target size and cost response, we have found—that is, the study has indicated that the cost of reduction is fairly stable through about the 4 to 6 million ton reduction level, and then rises rather exponentially, adding—doubling in cost for about every 2 million tons of reduction.

Finally, with respect to the phasing, Senator. We looked at—we compared two options; one of a 1990 reduction target of 5½ million, followed by a 1995 objective of 8 million; compared that to a straight reduction of 12 million tons by 1995.

We found that, of course, you get earlier results with the phased reduction. The cumulative reduction of the phased program by the year 2000 is greater than that of the 12-million-ton program. And finally, that the phased program does that at about half the cost of the other program.

Now, how do these points——

Senator WARNER. Mr. Wilson, I'm going to ask you, could we submit part of your testimony? I have stayed 1 hour beyond the appointed time I told Chairman McClure, and I've got considerable backup in other areas here in my Senate life. Is it possible that you could summarize?

Mr. WILSON. I can in an instant, just state that we feel there is a very strong relationship between the positions we favor and continued research in this area.

Freedom of choice encourages continued examination of technology, and this, we think, and the testimony you have heard today supports the desirability of that. These positions, I think, are entirely consistent with the continued emphasis upon—and that is an ACE position, continue the emphasis there.

We are pleased to have had this opportunity to speak to you.

[The prepared statement of Mr. Wilson follows:]

ACE

Alliance for Clean Energy
1901 N. Ft. Myer Drive, Twelfth Floor
Rosslyn, Virginia 22209
(703) 841-1781

Testimony of
James C. Wilson, President
of
Rocky Mountain Energy Company
Before the
Committee on Energy and Natural Resources
U.S. Senate
April 30, 1984

Mr. Chairman, Members of the Committee. I am James C. Wilson, President of Rocky Mountain Energy.

I am appearing before you today on behalf of the Alliance for Clean Energy. ACE, as we are known is a coalition of coal producers, transporters and consumers with over 30 member companies who would be directly impacted by pending acid rain legislation.

ACE membership includes most of the low sulfur coal producers in the United States with members in the east with operations in West Virginia, Virginia, Kentucky, Tennessee and Alabama, and in the west in Wyoming, Montana, Colorado, Utah, North Dakota and New Mexico.

ACE recognizes that acid rain is one of the most difficult issues facing the Congress and the country today. The environmental and economic consequences of legislating, or not legislating, a solution are enormous. Yet there remains substantial disagreement among experts about the science surrounding the causes and effects of acid rain.

ACE does not offer judgments on the state of the science of acid rain nor are we here to actively support a particular piece of legislation. What counsel we do offer to this Committee today is derived from two premises:

-- First, that many members of Congress concluded in the last Congress -- and may do so again this year or in 1985 -- that a legislative solution to the acid rain phenomenon is required. Consequently, if legislation is to be enacted, ACE wants to share with this Committee our views based on our experience and judgment.

-- Second, that as a group of coal producers, transporters and consumers, we know coal markets; we know the coal employment situation; and we understand the economics of coal use.

A COST EFFECTIVE SOLUTION

The essence of the ACE position is that if Congress decides to enact acid rain control legislation, it should be the most cost effective. And to be cost effective it must permit utilities to freely make the best economic choice between switching to low sulfur coal and scrubbing. Mr. Chairman, I am pleased that these concepts are embodied in the bill the Senate Environment and Public Works Committee reported recently.

ACE's position in favor of utility freedom of choice and against national mandatory scrubber legislation is based on several simple but, we believe, compelling arguments:

1. There are vast quantities of abundant and inexpensive low sulfur coal in the east as well as in the west which, if desired, can be used to substantially reduce sulfur emissions.
2. In most cases, utilities can achieve sulfur reductions much less expensively by converting to low sulfur coal rather than investing in and operating costly scrubbers.
3. Manadatory scrubbing legislation can, realistically, only be funded through a national tax which penalizes those regions of the country which have already achieved low SO_2 emissions levels.
4. SO_2 emissions can be reduced more rapidly using low sulfur coal and the large sludge disposal problem associated with scrubbers can be avoided.
5. The relatively modest reduction in high sulfur midwest coal mining jobs can be largely offset by jobs created in adjacent eastern low sulfur areas.

Mr. Chairman, let me discuss each of these points in more detail.

Abundance of Eastern and Western Low Sulfur Coal

There is a common myth that has been promulgated by supporters of mandatory scrubber legislation that low sulfur coal largely exists only in the west and, thus, switching to low sulfur coal will only entail use of western coal. This is simply untrue.

As Exhibit 1 shows, current economically recoverable U.S. low sulfur coal reserves amount to 7.6 billion tons in the east and 8.0 billion tons in the west, for a total of over 15 billion tons. The U.S. Department of the Interior's estimate of in-place low sulfur reserves is even higher at a total of 193.8 billion tons with 26.5 billion tons in the east.

These reserves of low sulfur coal are very large compared to recent U.S. annual production of low sulfur coal (see Exhibit 1) of only about 280 million tons of which 200 million tons was in the east. Furthermore, the current additional productive capacity of low sulfur coal, as estimated by Chase Econometrics, is another 115 million tons in the east and another 90 million tons in the west.

Thus, it is clear that there is ample low sulfur coal reserves and capacity in both the east and the west to substantially reduce sulfur emissions without the need for widespread scrubber use. In fact, less than 100 million tons/year of additional low sulfur production capacity would be needed to reduce SO_2 emissions by 7 million tons/year.

Mr. Chairman, low sulfur coal can contribute greatly to further SO_2 reductions as it has in the past. For, despite a 15% increase in coal use from 1970 to 1980, SO_2 emissions dropped 21% with 80% of the reductions due to use of low sulfur coal.

Cost of Scrubbing vs. Use of Low Sulfur Coal

A recent Congressional Office of Technology Assessment study (see Exhibit 2) concluded that mandatory scrubbing would cost U.S. consumers $1.4 billion per year more than a "freedom of choice" policy permitting utilities to reduce emissions by using low sulfur coal. This represents about $30 billion of additional electricity costs to U.S. consumers over the next 20 years. Studies by ICF, Inc., who have performed several analyses for the U.S. Environmental Protection Agency, (see Exhibit 3), place the savings of a "freedom of choice" policy at $2.0 billion/year or over $40 billion of additional consumer costs.

The reason the costs of scrubbing are so high is easy to understand. According to DOE estimates (see Exhibit 4) the capital cost of a scrubber that would remove 90% of the sulfur in Illinois basin coal is $122/KW of capacity in 1982 dollars or $61 million of capital cost for a 500 MW plant.. At 11% interest rate, the interest alone is about $7 million/year with total amortization of the investment at about $9 million/year. At a plant throughput of 1.2 million tons/year, the capital cost alone amounts to about $7.50/ton of additional cost. As shown in Exhibit 4, the annual operating costs for a scrubber on a 3.5% sulfur coal is about 4.6 mills/KWH or about $9/ton. So, overall, a scrubber would add about $16/ton (1982 $) or about $18/ton in 1984 dollars to the cost of processing each ton of coal.

Mandatory Scrubbing - Who Should Pay?

The proponents of mandatory scrubbing legislation have argued for a national utility tax to spread the enormous costs of scrubbing to consumers throughout the U.S. However, currently, there are only 9 states, including Ohio, Illinois and Indiana, that significantly exceed the EPA emissions levels; the remaining states have successfully implemented their State Implementation Plans by incurring the costs and taking the necessary actions to reduce emissions. Thus, there is a real equity issue involved. It is our view that consumers in most regions of the U.S., which already have achieved low SO_2 emissions, should not be taxed to pay for scrubbers in a few states that have not reduced emissions.

SO_2 Can Be Reduced Faster By Using Low Sulfur Coal

A sulfur reduction program based on switching to low sulfur coal could be implemented to 2 or 3 years. A capital intensive mandatory scrubbing program would take 5 to 7 years to implement as outlined in the Sikorski-Waxman Bill (H.R. 3400) where 1990 is the target year for substantial reductions.

The reasons for the differences in timing are two-fold:

- First, designing, engineering, fabricating and constructing costly customized scrubbing units takes a minimum of 4 to 5 years before full operation.
- By contrast, because of the availability and abundance of eastern and western capacity of low sulfur coal, utilities can easily and quickly shift to low sulfur

coal. In fact, two utilities in Michigan have recently announced such shifts beginning less than one year from now.

Exhibit 5 illustrates how a freedom of choice strategy allowing switches to low sulfur coal, as contracted with mandatory scrubbing (under H.R. 3400), can lead to earlier reductions in SO_2. By 1990, cumulative SO_2 emissions under the freedom of choice strategy are 33% or 9 million tons lower than mandatory scrubbing. By 1993, a mandatory scrubbing policy still results in fewer cumulative emissions. It isn't until 1995 that a program of mandatory scrubbing equals freedom of choice strategy and then, only at a very high cost to U.S. consumers.

The Jobs Issue

The propopents of mandatory scrubber legislation have argued that job losses in the midwest would be 50,000-80,000 if utilities were allowed to use low sulfur coal to meet lower sulfur emission requirements. ACE believes these estimates are grossly overstated and that this issue is poorly understood, in part, because of the common misunderstanding of the large amount of current and potential eastern low sulfur coal mining jobs.

In discussing coal mining jobs, Mr. Chairman, it may be instructive to review historical trends. Between 1923 and 1969, employment in bituminous coal mining in the U.S. fell from more than 704,000 to fewer than 125,000, a decline of 82%. By 1979, however, employment in America's mines had doubled to more than 250,000 and is expected to increase to nearly 350,000 by 1995 as coal use continues to increase.

In order to put the employment question in some perspective, ACE commissioned several outside studies and ANR performed its own analysis, comparing a feasible, least cost approach involving low sulfur coal (similar to S. 768) and the mandatory scrubber approach of Sikorski-Waxman (H.R. 3400). (See Exhibit 6).

These studies, including a recent study by ICF, Inc., concluded that there are only two states -- Ohio and Illinois -- that would lose more than 1000 high sulfur coal mining jobs as a result of a "freedom of choice" policy which permitted compliance using low sulfur coal. By contrast, 17 states would gain more than 1000 low sulfur mining jobs including Virginia, West Virginia, Kentucky, Arkansas, Louisiana, Texas, New Mexico, Colorado, Utah, Wyoming, Montana, North Dakota, Arizona, Oklahoma, Alabama, Pennsylvania and Indiana.

Since the total estimated mining employment loss in Ohio and Illinois is estimated to be less than 12,000, and associated service jobs might be another 12,000, the annual cost of a mandatory scrubber program would be almost $80,000/year per job saved -- a very costly jobs program.

We do not mean to make light of job losses in any state. However, we would note that some of the highest unemployment in the mining fields is in low sulfur coal producing areas, in Virginia, eastern Kentucky and southern West Virginia. In fact, if mandatory scrubber legislation were enacted, it is certain that there would be job losses in the low sulfur coal mining regions as the small economic premium for low sulfur coal vanishes.

It is clear that the relatively modest reduction in high sulfur midwest coal mining jobs that would occur under a freedom of choice bill would be largely offset by new jobs created in adjacent low sulfur eastern coal regions. However, to the extent there are dislocations, these can be addressed through a targeted assistance program to affected miners rather than a costly scrubber program for the nation.

It is clear, in general terms, that the job impact of the kind of acid rain control program this committee is considering is far from the catastrophe some would have you believe.

New Technology Development

Let me turn now to new technology for scrubbers.

As you well know, the current generation of scrubbers has problems and are far from ideal. Technological controls are currently expensive to install and just as costly to operate. And the current generation of scrubbers merely transform one environmental problem to another. For example, it is estimated that 3 1/2 tons of sludge must be disposed of for each ton of SO_2 removed by conventional scrubbing. This is an issue which has received almost no serious attention from the environmental community and those who advocate mandatory scrubbing.

A national program which mandates installation of the current technology of scrubbers over the next six years would virtually foreclose development of new technological approaches. The huge capital expenditures necessitated by mandating scrubbers also absorbs funding for necessary research and development and would displace the funding for improved technologies. At the same time it would drastically penalize the rest of the economy and the nation.

Emission Caps and Offsets

Consistent with ACE's position that acid rain reduction be achieved in a cost effective manner, we also recommend that the Committee not include emissions "cap" and "offset" provisions in the earlier Committee-reported bill. These mechanisms for limiting SO_2 are both economically inefficient and administratively burdensome, and could needlessly hinder industrial growth.

For example, emissions offsets in areas which have already cleaned up may simply not be available. States such as Louisiana and Connecticut, which rely mainly on gas- or oil-fired electrical power, currently produce little SO_2. The construction of coal-fired industrial boilers in those States could produce emissions for which offsets are unavailable. And there may be as many as eight other States, who are already in compliance with their State Implementation Plans, including Arkansas and Michigan, which could have problems finding the reductions needed to accommodate growth. Offsets for these States may be available only through interstate trades, whose feasibility is untested.

CONCLUSION

Mr. Chairman, acid rain control legislation will have a significant effect on the long-term U.S. energy supply/demand picture. Coal is clearly the fuel of choice for baseload generation of electricity. It is less expensive than alternative fuels and has the potential to further reduce dependence upon imported oil. Increasing the use of coal for domestic electricity generation should thus be a high priority. Yet, certain acid rain legislative alternatives involving mandatory scrubbing will greatly constrain the increased use of eastern and western low sulfur coal -- with little or no environmental benefit.

Congress, in the context of fashioning acid rain legislation, can and should only revise the environmental laws in a manner assuring that our environment will be protected without undue cost to consumers. Such a revision requires doing several things.

First, in any new legislation environmental goals should be attained at the least cost. Mandatory use of scrubbers should be avoided, replaced with clear and definite performance standards, allowing those burning coal to elect the least cost method of complying with those standards.

Second, conversion to coal from alternative fuels should be encouraged, again by setting clear, reasonable performance standards for those units.

Third, new technology must be developed quickly to permit the clean burning of high -- as well as low -- sulfur coal. Legislative barriers to implementation of new technology should be avoided. A freedom of choice strategy will give the greatest incentive to new coal technology developments.

Employment displacements within the ordinarily volatile coal industry should be addressed directly by assistance targeted to those whose employment is threatened without massive distortions to the coal market.

Mr. Chairman, all we ask is that the Federal government give low sulfur coal producers the chance to compete by rejecting policies which would consciously exclude us from the marketplace at the expense of the consuming public.

Thank you for the opportunity to present our views. I will be happy to answer any questions you may have.

EXHIBIT 1A

RESERVE BASE OF U.S. LOW SULFUR COAL
(Millions of Short Tons)

	Deep	Surface	Total
East	21,200	5,300	26,500
West	99,400	67,900	167,300
Total	120,600	73,200	193,800

Source: United States Dept. of Interior, U.S. Bureau of Mines Information Circular 8680.

CONSERVATIVE ESTIMATE OF U.S. LOW SULFUR COAL RESERVE BASE[1]
(Millions of Short Tons)

East	7,585.0
West	8,036.1
Total	15,621.1

[1] Less than 1% sulfur, greater than 9,000 Btu./Lb.; includes metallurgical coal.

Sources: International Coal Trade Project, Baseline Projections, Tier III Supply Curves, October 1982; Chase Econometrics.

Coal Review Update, Regional Production and Minemouth Prices 1981, Spring 1982; Data Resources Inc.

Cost and Quality of Fuels for Electric Utility Plants 1981 Annual; DOE/EIA, Office of Coal Nuclear, Electric and Alternate Fuels, Sept. 1982.

ANR Analysis.

EXHIBIT 1B

CAPACITY OF U.S. LOW SULFUR COAL[1]
(Millions of Short Tons)

	East	West	Total
Productive Capacity[2]	317.7	168.8	486.5
1981 Production [3]	202.5	79.9	282.4
1981 Excess Capacity	115.2	88.9	204.1

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[1] Less than 1% sulfur, greater than 9,000 Btu/Lb.; includes metallurgical coals.

[2] Productive capacity was estimated using Chase Econometric supply curves.

[3] Dec. 1982, U.S. Dept. of Energy -- Energy Information Administration; Coal Production - 1981.

COMPARISON OF SOCIETAL COSTS OF SIKORSKI-WAXMAN TO FREEDOM OF CHOICE

	Sikorski-Waxman (No Fund)	Freedom of Choice*
Annual Costs of the Program (1982$)	$4.90 Billion	$3.45 Billion
Residential Electric Avg. Rate Increases (%)		
Alabama	1.9 - 2.8%	1.0 - 2.1%
Florida	2.1 - 2.7	1.3 - 2.4
Georgia	8.3 - 9.0	7.6 - 9.0
Illinois	4.3 - 4.8	3.7 - 4.6
Indiana	12.1 - 14.0	7.2 - 10.6
Iowa	0 - .3	0 - .3
Kansas	0 - .1	0 - .1
Kentucky	12.8 - 14.3	6.1 - 8.0
Maine	.2	.2
Maryland	2.1 - 2.9	2.1 - 2.9
Massachusetts	.8 - .9	.8 - .9
Michigan	1.8 - 2.5	.6 - 1.3
Minnesota	.7 - 1.7	.7 - 1.7
Mississippi	3.5 - 3.9	1.5 - 3.0
Missouri	9.9 - 10.2	2.3 - 3.1
Montana	.5 - 1.0	.5 - 1.0
Nebraska	.1 - .2	.1 - .2
New Hampshire	3.1 - 3.7	3.1 - 3.7
New Jersey	.9 - 1.3	.9 - 1.3
New York	1.2 - 1.5	1.2 - 1.5
North Carolina	1.3 - 3.1	1.3 - 3.1
North Dakota	1.0 - 2.8	1.0 - 2.8
Ohio	11.7 - 12.9	7.1 - 8.5
Pennsylvania	4.1 - 4.7	3.3 - 3.8
South Carolina	2.0 - 3.4	2.0 - 3.4
South Dakota	.9 - 1.4	.9 - 1.4
Tennessee	15.6	3.2 - 8.3
Texas	.1 - .3	.1 - .3
Virginia	.4 - 1.3	.4 - 1.3
West Virginia	7.0 - 7.3	6.5 - 7.5
Wisconsin	2.9 - 2.9	.4 - .4
Total of Lower 48 States Affected	3.2 - 3.7%	2.0 - 2.8%

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*Under the freedom of choice least cost alternative approximately 30% of the targeted plants would choose to use scrubbers (per personal communication with the OTA staff).

Source: An Analysis of the Sikorski/Waxman Acid Rain Proposal: H.R. 3400, "The National Acid Deposition Control Act of 1983, OTA Oceans and Environment Program, 6/21/83, Revised 7/12/83.

EXHIBIT 3

ICF INCORPORATED International Square, 1850 K Street, Northwest, Washington, D.C. 20006 (202) 862-1100

October 4, 1983

MEMORANDUM

TO : Clark R. Burley
American Natural Resources Company

FROM : Daniel E. Klein DK
C. Hoff Stauffer, Jr.

SUBJECT: Coal and Electric Utility Market Impacts of ANR's Proposed Phased Reduction Proposal for Reducing Sulfur Dioxide Emissions

This memorandum presents ICF's findings of an analysis of a sulfur dioxide emissions reduction program requiring interim reductions between 1985 and 1995. This proposal was outlined in a letter from William T. McCormick, Jr. of ANR to Alvin Alm of the EPA, dated September 8, 1983.

EXECUTIVE SUMMARY OF FINDINGS

- Two scenarios were examined for the 1985 to 1995 forecast period. The base case represents a reference case forecast that assumes no acid rain mitigation legislation. The ANR case is our analysis of the acid rain mitigation program outlined in ANR's letter to EPA, and subsequently articulated during our discussions with ANR. The ANR case requires sulfur dioxide emissions reductions of about three million tons in 1985, 6.5 million tons in 1990, and an ultimate reduction of 8.0 million tons by 1995. Cost-effective strategies for reducing sulfur dioxide emissions are permitted in the ANR case. No near-term constraints (before 1995) were assumed with respect to increasing coal production or transportation.

- Costs -- The ANR case is forecasted to lead to increased annual costs of 1.8 billion dollars by 1995. Because scrubber retrofits are generally not chosen as a cost-effective strategy for reducing sulfur dioxide emissions, cumulative capital costs increase by only 2.5 billion dollars by 1995. These increased costs raise annualized electricity rates by an average of 1.6 percent in the 31-Eastern States, with no state incurring more than a 6.1 percent increase.

- Regional Coal Production -- In the ANR case, fuel switching is often selected as a least-cost means of reducing sulfur dioxide emissions. Accordingly, forecasted coal production tends to decline in higher-sulfur regions such as Northern Appalachia and the Midwest, and increase in lower-sulfur regions such as Central Appalachia and the Rockies.

- Employment Shifts -- For the United States as a whole, the forecasted number of jobs in coal mining and transportation show only modest changes between the ANR case and the base case. However, commensurate with the coal production shifts from higher-sulfur to lower-sulfur regions, the ANR case could also result in jobs shifting among regions. In both 1990 and 1995, the number of coal mining jobs in higher-sulfur regions (primarily Ohio and the Midwest) would be about 13 thousand fewer than in 1980.

FRAMEWORK FOR ANALYSIS

We have analyzed two scenarios for the 1985 to 1995 forecast period.

The base case represents a reference case forecast that assumes no acid rain mitigation legislation. This is the same base case that was specified by EPA and used in recent acid rain analyses.

The ANR case was developed from ANR's proposed phased-in sulfur dioxide reduction program, as expressed in a September 8, 1983 letter to EPA and subsequently articulated in meetings between ICF and ANR. The requirements of the ANR case are as follows:

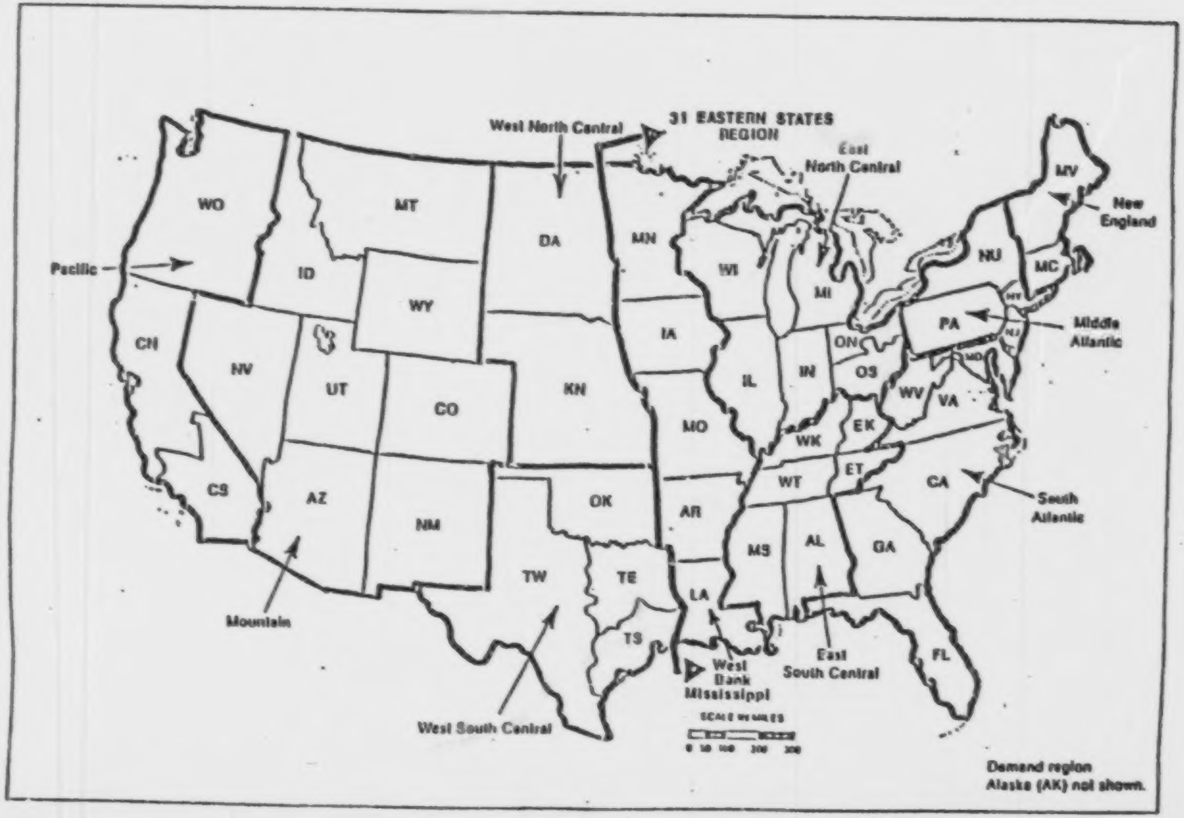
- Sulfur dioxide emissions from existing sources would be reduced below 1980 levels. A three million ton reduction would be scheduled by 1985; a 6.5 million ton reduction would be scheduled by 1990; and an eight million ton reduction would be scheduled by 1995.

- Emission reductions in 1985, 1990, and 1995 would be allocated among a 31-Eastern State region, as shown in Figure 1. The allocation formula was based upon excess emissions (above a level of 1.5 pounds of sulfur dioxide per million Btu) on a plant-by-plant basis. That is, each state's reduction liability was based on its percentage of excess emissions in 1980 with respect to the total for the 31-Eastern State region.

- Growth in sulfur dioxide emissions from new plants or sources was not required to be offset. New plants and sources were required to meet current NSPS only.

FIGURE 1

ACID RAIN MITIGATION STUDY REGION


West North Central
31 EASTERN STATES REGION
East North Central
New England
Middle Atlantic
South Atlantic
Pacific
Mountain
West South Central
West Bank Mississippi
East South Central
WO
MT
DA
MN
WI
MI
MV
NU
MC
ID
WY
IA
PA
NY
NJ
MD
CN
NV
UT
CO
KN
IL
IN
ON
OS
WV
VA
MO
WK
EK
CS
AZ
NM
OK
AR
WT
ET
CA
TW
TE
TS
LA
MS
AL
GA
FL
SCALE IN MILES
0 50 100 200 300

Demand region
Alaska (AK) not shown.

ICF INCORPORATED

- Interstate trading of emission reductions was permitted, as were other cost-effective strategies including retrofitting scrubbers, dispatching plants in a least-emissions manner, switching to lower-sulfur fuels, and coal blending.

- No near-term constraints (i.e., before 1995) were assumed with respect to increasing coal production or transportation.

- Increases in sulfur dioxide emissions at those powerplants converting to coal were not required to be offset provided that the applicable emissions limit for these sources was no more than 1.5 pounds of sulfur dioxide per million Btu. These increases were treated as emission credits.

- Industrial facilities were assumed to reduce emissions through shifts to lower-sulfur fuels by about 0.4 million tons in 1995, and nothing before then. This is consistent with other analyses by ICF for EPA.

Tables 1, 2, and 3 develop the required reductions in utility sulfur dioxide emissions at existing plants. Because of the utility reconversion credits and the industrial emissions offsets (in 1995), the net reductions for the electric utilities differ slightly from the specified reductions of 3.0, 6.5, and 8.0 million tons below 1980 levels.

POTENTIAL MARKET IMPACTS

The ANR case for implementing an acid rain mitigation strategy is forecasted to lead to significantly different coal and electric utility market conditions from the base case. These changes are discussed below.

Changes in Sulfur Dioxide Emissions

Tables 4, 5, and 6 present our forecasts for sulfur dioxide emissions.

Table 4 summarizes the changes in emissions. By assumption, the electric utility sector is responsible for all of the emissions until 1995, when a small contribution from the industrial sector is assumed. Because of reconversion credits and small changes outside the 31-Eastern state region, the total reductions differ slightly from the amount specified from existing utilities.

Table 5 presents additional detail on sulfur dioxide emissions, by fuel type and by sector. Table 6 details the changes in sulfur dioxide emissions by state within the 31-Eastern state region.

Cost Forecasts

Table 7 summarizes the costs to the electric utility and industrial sectors. In the electric utility sector, the ANR case would lead to higher costs of up to 1.8 billion dollars on an annual basis by 1995. Because scrubber retrofits are generally not chosen as an emission reduction strategy, cumulative capital costs (relative to the base case) amount to only 2.5 billion dollars by 1995.

The average cost per ton of sulfur dioxide removed increases over time as the total amount of required reductions increases. However, the marginal cost per ton removed is forecasted to change little between 1990 and 1995, even though utilities must remove an additional one million tons of sulfur dioxide. This reflects not only a relative flatness in this portion of the "supply curve" for emissions reductions, but also shifts in this supply curve over time. These shifts in the costs of reducing sulfur dioxide emissions can result from both input assumptions to the forecast (e.g., the changes over time in the assumed price relationship among high- and low-sulfur residual oil and natural gas), as well as the forecasted relationship between high-sulfur and low-sulfur coal prices over time and the availability of utility capacity over time.

Industrial coal costs are estimated to increase by 0.6 billion dollars in 1995, reflecting the assumed shift to lower-sulfur fuels. Industrial coal costs are also slightly higher in 1990 even though no fuel shifting in this sector is assumed to have begun, because of coal price increases induced by electric utility fuel shifting.

Table 8 presents the forecasted changes in annualized costs for the electric utilities in the 31-Eastern states. These costs are estimated as changes from the base case which assumed no acid rain mitigation legislation.

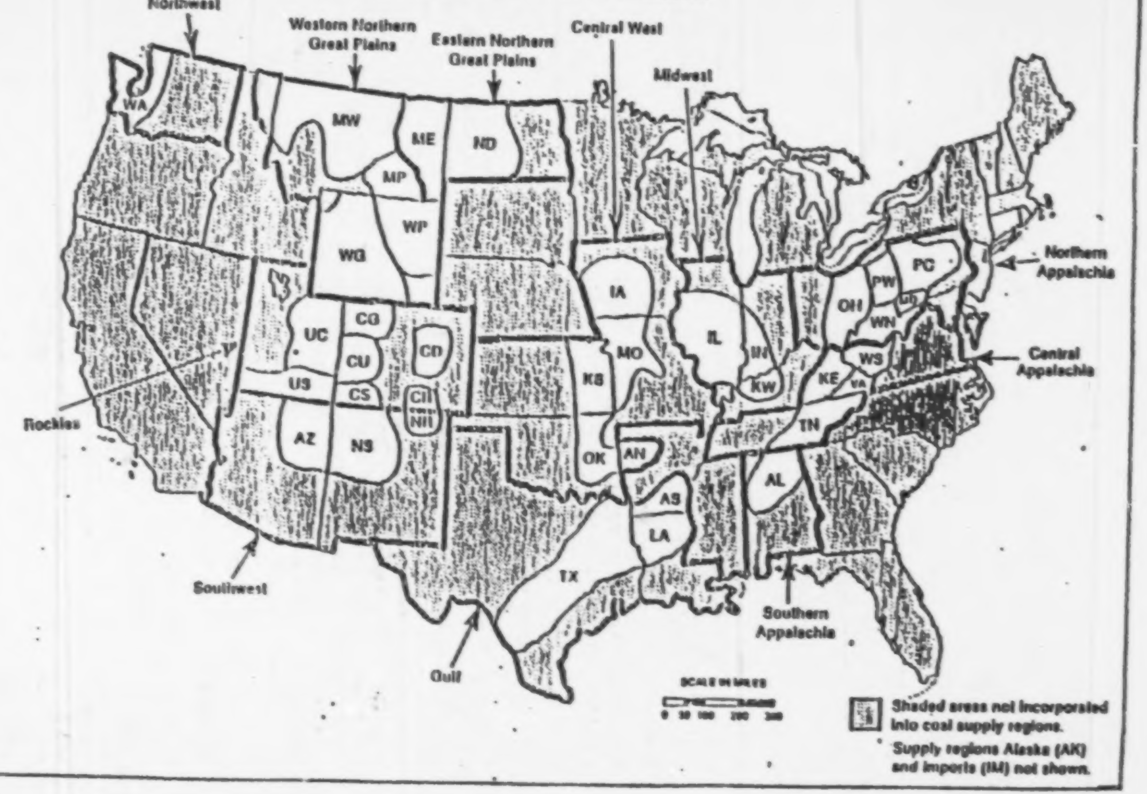
Table 9 presents the forecasted changes in annualized electric utility rates in the 31-Eastern states. These changes in rates are computed as the changes in annualized costs (as shown in Table 8) per Kwh relative to a 1980 rate base. Under conventional rate-making practices, first-year rate increases would be higher than increases based on annualized costs because of capital recovery patterns. However, since the ANR case involves relatively ~~little~~ incremental capital, first-year costs would not be substantially different from annualized costs.

Regional Coal Production

Consistent with the shifts to lower-sulfur coals by utility and industrial boilers, the ANR case would also lead to a shift in the forecasted coal production by region. Table 10 shows coal production by aggregate region for the ANR case, while Table 11 shows the base case forecasts. Table 12 details these aggregate region production forecasts by sulfur content. Attachments A-1 and A-2 present production forecasts for the individual coal supply regions. Coal supply regions are mapped in Figure 2.

FIGURE 2

CEUM COAL SUPPLY REGIONS


Northwest
Western Northern Great Plains
Eastern Northern Great Plains
Central West
Midwest
Northern Appalachia
Central Appalachia
Rockies
Southwest
Gulf
Southern Appalachia
WA
MW
ME
MP
ND
WP
WG
UC
CG
CU
CD
US
CS
CN
NN
AZ
NS
IA
MO
KS
OK
AN
AS
LA
TX
IL
IN
KW
KE
VA
WS
WN
OH
PW
PC
TN
AL
SCALE IN MILES
0 50 100 200 300

Shaded areas not incorporated into coal supply regions.

Supply regions Alaska (AK) and Imports (IM) not shown.

Under the ANR case, higher-sulfur regions such as Northern Appalachia and the Midwest are forecasted to have lower levels of production than would have been the case in the absence of acid rain mitigation legislation. Our forecasts indicate that production from these regions, particularly in Ohio, Illinois, Indiana, and Western Kentucky could be less than 1980 production levels. Conversely, lower-sulfur regions such as Central Appalachia and parts of the West are forecast to have significantly higher levels of coal production.

For this analysis, few shifts to lower-rank coals were forecast. This reflects an assumption that individual boilers designed to burn bituminous coals would not find shifting to lower-rank coals economic after consideration of powerplant modification costs, capacity derates, heat rate increases, and increased costs for flame stabilization. To the extent that such shifts would occur, the estimated costs impacts would be lower, and the forecasted production increases in Eastern and Western bituminous low-sulfur coal fields would be less.

The regional coal production levels are sensitive not only to the acid rain legislation assumptions, but also to the base case assumptions. The base case, initially specified by EPA, may overstate high-sulfur coal production. If so, then production and job losses (from 1980 levels) in high-sulfur regions resulting from acid rain legislation could be understated.

Changes in Coal Mining and Transportation Employment

The potential shifts in regional coal production as a result of acid rain mitigation legislation could also lead to coal mining job losses in some regions, and gains in other regions. Additionally, coal distribution patterns would also change, leading to employment changes in the transportation industries.

Tables 13 and 14 summarize the changes in coal mining and the transportation employment for the base case and ANR case over the 1985 to 1995 period. Attachments A-1 through A-4 develop these estimates in greater detail.

-- Coal Mining

Because coal demand is forecasted to grow in all cases, national coal mining employment is also forecasted to grow. Our estimates indicate that the net changes in coal mining employment in both the base case and ANR case are similar. Rather than creating or eliminating mining jobs in total, the ANR case would instead lead to job shifts among coal producing regions.

Under the ANR case, coal production and mining employment would decline from 1980 levels in higher-sulfur regions such as the Midwest and parts of Northern Appalachia. A forecasted decline is not necessarily the same as forced mine closings and/or layoffs, since between 1980 and 1995 some mines will have depleted their reserves and some miners will have retired.

Forecasted employment levels do not rise or fall proportionally to changes in regional coal production, as had been the case in earlier preliminary analyses which relied upon the use of historic productivity estimates. For example, production in some regions (such as Colorado Uinta) is forecasted to rise at a much faster rate than employment levels. This is because much of the current production in these regions is comprised of lower productivity metallurgical mines, whereas the growth in production will largely be in higher productivity steam coal mines.

In another example, intraregional shifts in coal production by sulfur content can lead to greater employment requirements without necessarily increasing total regional production. For example, in Central Pennsylvania, total production in 1995 is forecasted to decline from 1980 levels. However, in addition to this forecasted decline, a shift from higher-sulfur coals to lower-sulfur coals occurs. Because high-sulfur coals generally come from higher productivity mines (i.e., fewer miners per ton of coal produced) than low-sulfur coals, average productivity as a result of these shifts is forecast to decline from base case levels. This in turn results in a greater number of workers needed to support a lower level of production.

-- Coal Transportation

The production shifts forecasted under the ANR case would lead to greater requirements for coal transportation. As indicated in Attachments A-3 and A-4, coal transportation requirements would rise by approximately 60 billion ton-miles in 1995 above the levels forecasted in the base case. This in turn would lead to about 2,000 additional jobs required for coal transportation, primarily in rail and truck movements. Because the methodology for estimating transportation employment used in this analysis focuses on those directly involved in the coal movements, we believe these estimates are conservative and are likely to understate the number of additional workers needed.

-- Related Employment Changes

The estimated changes in coal mining and transportation employment presented in this analysis do not include shifts in related industries. In those regions where mining employment losses are forecasted to occur, there would likely be additional losses associated with the industries supplying those mines and workers. Conversely, there would likely be gains in industries supplying mines and workers in those regions which increased production. Similarly, changes in employment in related manufacturing industries (particularly those for scrubbers and mining equipment) were not assessed. Further, this analysis does not include any changes in employment and/or standards of living associated with the changes in total national costs of meeting coal and electricity demands.

TABLE 1

1985 UTILITY SULFUR DIOXIDE LIMITS IN THE AHR CASE FOR EXISTING UTILITY PLANTS ONLY
(10^3 tons of SO_2)

	1980 Utility Emissions	Utility Reconversion Credits	Utility Required Reductions	1985 Utility Emission Limits[a]
NV	97.31	-	14.6	82.71
NC	292.14	-	21.6	270.54
NY[b]	478.77	46.10	61.2	463.67
NJ	103.30	-	9.1	94.20
PA	1,423.83	2.76	238.0	1,188.59
VA	157.49	13.80	2.6	168.69
MD	276.95	11.54	32.7	255.79
WV	983.67	-	184.5	799.17
CA	655.44	11.36	32.2	634.60
GA	703.89	3.71	120.1	587.50
FL	691.77	-	83.3	608.47
OH[c]	2,184.99	-	498.1	1,686.89
MI	607.95	-	81.7	526.25
IN	1,673.36	-	405.2	1,268.16
IL	1,109.71	-	231.6	878.11
WI	488.06	-	107.6	380.46
KY[d]	1,028.71	-	225.3	803.41
TN[e]	1,100.63	-	221.7	878.93
AL[f]	344.87	-	45.0	299.87
MS	122.05	-	20.5	101.55
MN	159.90	-	13.2	146.70
IA	236.08	-	41.6	194.48
MO	1,227.41	-	308.6	918.81
AR	26.74	-	-	26.74
LA	18.85	-	-	18.85
Total	16,193.87	89.27	3,000.0	13,283.14

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[a] Sulfur dioxide limits equal 1980 emissions plus reconversion credits minus required reductions.

[b] New York: CEUM Regions NU and NY.

[c] Ohio: CEUM Regions OH and OS.

[d] Kentucky: CEUM Regions EK and WK.

[e] Tennessee: CEUM Regions ET and WT (includes an adjustment for TVA plants located in the northern part of Alabama modeled as part of the utility capacity in TN).

[f] Alabama: (does not include TVA plants located in Alabama but modeled as part of the utility capacity in TN).

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TABLE 2

1990 UTILITY SULFUR DIOXIDE LIMITS IN THE AMR CASE FOR EXISTING UTILITY PLANTS ONLY
(10^3 tons of SO_2)

	1980 Utility Emissions	Utility Reconversion Credits	Utility Required Reductions	1990 Utility Emission Limits[a]
NV	97.31	-	31.6	65.71
NC	292.14	8.45	46.7	253.89
NY[b]	478.77	97.97	132.7	444.04
NJ	103.30	17.42	19.7	101.02
PA	1,423.83	2.76	515.6	910.99
VA	157.49	22.15	5.6	174.04
MD	276.95	12.62	70.8	218.77
WV	983.67	-	399.8	583.87
CA	655.44	11.36	69.7	597.10
GA	703.89	3.71	260.3	447.30
FL	691.77	-	180.5	511.27
OH[c]	2,184.99	-	1,079.3	1,105.69
MI	607.95	-	177.0	430.95
IN	1,673.36	-	877.9	795.46
IL	1,109.71	-	501.7	608.01
WI	488.06	-	233.2	254.86
KY[d]	1,028.71	-	488.1	540.61
TN[e]	1,100.63	-	480.4	620.23
AL[f]	344.87	-	97.5	247.37
MS	122.05	-	44.4	77.65
MN	159.90	-	28.6	131.30
IA	236.08	-	90.1	145.98
MO	1,227.41	-	668.8	588.61
AR	26.74	-	-	26.74
LA	18.85	-	-	18.85
Total	16,193.87	176.44	6,500.0	9,870.31

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a/ Sulfur dioxide limits equal 1980 emissions plus reconversion credits minus required reductions.

b/ New York: CEUM Regions NU and NY.

c/ Ohio: CEUM Regions ON and OS.

d/ Kentucky: CEUM Regions EK and WK.

e/ Tennessee: CEUM Regions ET and WT (includes an adjustment for TVA plants located in the northern part of Alabama modeled as part of the utility capacity in TN).

f/ Alabama: (does not include TVA plants located in Alabama but modeled as part of the utility capacity in TN).

TABLE 3

1995 UTILITY SULFUR DIOXIDE LIMITS IN THE ANR CASE FOR EXISTING UTILITY PLANTS ONLY (10^3 tons of SO_2)

	1980 Utility Emissions	Utility Reconversion Credits	Utility Required Reductions	Industrial Reductions	1995 Utility Emission Limits[a]
NV	97.31	-	38.9	3.8	62.21
NC	292.14	8.45	57.5	-	243.09
NY[b]	478.77	97.97	163.3	32.3	445.74
NJ	103.30	17.42	24.2	14.7	111.22
PA	1,423.83	2.76	634.6	80.0	871.99
VA	157.49	22.15	6.9	13.2	185.94
MD	276.95	12.62	87.1	-	202.47
WV	983.67	-	492.0	19.4	511.07
CA	655.44	11.36	85.8	21.2	602.20
GA	703.89	3.71	320.4	13.8	401.00
FL	691.77	27.50	222.2	5.9	502.97
OH[c]	2,184.99	-	1,328.3	5.2	861.89
MI	607.95	-	217.9	41.7	431.75
IN	1,673.36	-	1,080.5	-	592.86
IL	1,109.71	-	617.5	37.4	529.61
WI	488.06	-	287.0	20.0	221.06
KY[d]	1,028.71	-	600.7	4.2	432.21
TN[e]	1,100.63	-	591.3	22.4	531.73
AL[f]	344.87	-	120.0	29.9	254.77
MS	122.05	-	54.7	-	67.35
MN	159.90	-	35.2	7.0	131.70
IA	236.08	-	110.9	-	125.18
MO	1,227.41	-	823.1	13.1	417.41
AR	26.74	-	-	-	26.74
LA	18.85	-	-	-	18.85
Total	16,193.87	203.94	8,000.0	385.2	8,782.01

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[a] Sulfur dioxide limits equal 1980 emissions plus reconversion credits minus required reductions plus industrial reductions.

[b] New York: CEUM Regions NU and NY.

[c] Ohio: CEUM Regions ON and OS.

[d] Kentucky: CEUM Regions EK and WK.

[e] Tennessee: CEUM Regions ET and WT (includes an adjustment for TVA plants located in the northern part of Alabama modeled as part of the utility capacity in TN).

[f] Alabama: (does not include TVA plants located in Alabama but modeled as part of the utility capacity in TN).

TABLE 4

REDUCTIONS IN SO_2 EMISSIONS -- TOTAL U.S.
(million tons/year)

	Changes from Base Case to ANR Case		
	1985	1990	1995
Utility Reductions	-3.03	-6.46	-7.47
Industrial Reductions	-	-	-0.39
Total	-3.03	-6.46	-7.86

TABLE 5

SO_2 EMISSION FORECASTS
(millions of tons)

	1980	1985 AMR Case	1985 Change from Base	1990 AMR Case	1990 Change from Base	1995 AMR Case	1995 Change from Base
Utility SO_2 Emissions							
31-Eastern States							
Existing							
Coal	14.92	12.25	-3.10	9.07	-6.60	8.27	-7.23
Oil/Gas	1.27	1.03	-	0.80	-0.01	0.51	-0.39
	16.19	13.28	-3.10	9.87	-6.61	8.78	-7.62
New	-	0.32	+0.05	0.84	+0.13	1.17	+0.10
Total 31-Eastern States	16.19	13.60	-3.05	10.71	-6.48	9.95	-7.52
Other	1.19	1.75	+0.02	2.07	+0.02	2.26	+0.05
Total U.S.	17.38	15.35	-3.03	12.78	-6.46	12.21	-7.47
Industrial SO_2 Emissions							
31-Eastern States	2.60	2.55	-	3.00	-	2.93	-0.39
Other	0.32	0.36	-	0.48	-	0.58	-
Total U.S.	2.92	2.91	-	3.48	-	3.51	-0.39
Utility and Industrial SO_2 Emissions							
31-Eastern States	18.79	16.15	-3.05	13.71	-6.48	12.88	-7.91
Other	1.51	2.11	+0.02	2.55	+0.02	2.84	+0.05
Total U.S.	20.30	18.25	-3.03	16.26	-6.46	15.72	-7.86

TABLE 6

CHANGES IN ELECTRIC UTILITY SO_2 EMISSIONS — 31-EASTERN STATES
(thousands of tons)

	Changes from Base Case to ANR Case		
	1985	1990	1995
Maine/Vermont/New Hampshire	-23	-21	-29
Massachusetts/Connecticut/Rhode Island	-	-	-71
New York	-10	-91	-168
Pennsylvania	-	-126	-117
New Jersey	-	-8	-24
Maryland/Delaware/District of Columbia	-23	-136	-175
Virginia	-76	-83	-132
West Virginia	-71	-345	-469
North and South Carolina	-13	-159	-177
Georgia	+7	-132	-267
Florida	-95	-237	-381
Ohio	-370	-941	-978
Michigan	-31	-188	-196
Indiana	-745	-1,132	-1,139
Illinois	-284	-516	-558
Wisconsin	-49	-476	-461
Kentucky	-70	-176	-276
Tennessee	-370	-539	-629
Alabama	-139	-101	-91
Mississippi	-33	-82	-83
Minnesota	-23	-24	-62
Iowa	-41	-83	-88
Missouri	-579	-883	-936
Arkansas	-4	-7	-11
Louisiana	-6	+4	-1
Total 31-Eastern States	-3,048	-6,482	-7,519

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TABLE 7

UTILITY AND INDUSTRIAL COST FORECASTS

	Changes from Base Case to ANR Case			
	1980	1985	1990	1995
ELECTRIC UTILITY COSTS				
Annual Costs (billions of 1982 $/yr.)				
31-Eastern States	-	+0.3	+1.2	+1.8
Other	-	-	-	-
Total	-	+0.3	+1.2	+1.8
Cumulative Capital Costs (billions of 1982 $)				
31-Eastern States	-	+0.4	+2.6	+2.2
Other	-	-	-	+0.3
Total	-	+0.4	+2.6	+2.5
Average Cost Per Ton SO_2 Removed (1982 $/ton)				
31-Eastern States	-	+113	+183	+238
Other	-	-	-	-
Total	-	+106	+190	+245
Marginal Cost Per Ton SO_2 Removed (1982 $/ton)				
31-Eastern States	-	+312	+484	+477
Other	-	-	-	-
Total	-	+312	+484	+477
Percent Change in Electricity Rates (%)				
Annualized				
31-Eastern States Average	-	0.4	1.2	1.6
Maximum Any State	-	2.3[a]	5.3[a]	6.1[b]
Scrubber Capacity (Gw)				
31-Eastern States	16.7	-	+6.3	+6.5
Other	18.8	-	-	-
Total U.S.	35.5	-	+6.3	+6.5
INDUSTRIAL COSTS (billions of 1982 $/yr.)				
31-Eastern States	-	-	+0.1	+0.6
Other	-	-	-	-
Total	-	-	+0.1	+0.6

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a/ Mississippi.

b/ Ohio, Indiana.

TABLE 8

CHANGE IN UTILITY ANNUALIZED COSTS — 31-EASTERN STATES (million 1982 $/year)

	Changes from Base Case to ANR Case		
	1985	1990	1995
Maine/Vermont/New Hampshire	+3	-11	-7
Massachusetts/Connecticut/Rhode Island	-6	+23	+30
New York	+31	+13	+20
Pennsylvania	+9	+82	+145
New Jersey	+5	+8	-8
Maryland/Delaware/District of Columbia	+11	+21	+25
Virginia	+26	+12	+6
West Virginia	+66	+135	+128
North and South Carolina	+77	+18	-11
Georgia	+25	+24	+55
Florida	+29	+26	+82
Ohio	+86	+307	+492
Michigan	+54	+44	+54
Indiana	-16	+102	+303
Illinois	-26	+21	+33
Wisconsin	+47	+98	+107
Kentucky	-94	+18	+76
Tennessee	-28	+37	+66
Alabama	-30	+26	-15
Mississippi	+29	+68	+68
Minnesota	-15	-17	+1
Iowa	+2	+28	+25
Missouri	-8	+83	+109
Arkansas	+8	+18	+11
Louisiana	-1	+2	-3
Total 31-Eastern States	+343	+1,188	+1,791

TABLE 9

PERCENT CHANGE IN ELECTRICITY RATES BASED ON FORECASTED CHANGES IN UTILITY ANNUALIZED COSTS — 31-EASTERN STATES

	Changes from Base Case to AHR Case[a]		
	1985	1990	1995
Maine/Vermont/New Hampshire	+0.3	-0.8	-0.5
Massachusetts/Connecticut/Rhode Island	-0.2	+0.7	+0.7
New York	+0.4	+0.1	+0.2
Pennsylvania	+0.1	+0.9	+1.5
New Jersey	+0.2	+0.3	-0.2
Maryland/Delaware/District of Columbia	+0.5	+0.8	+0.8
Virginia	+1.0	+0.5	+0.2
West Virginia	+1.9	+3.9	+3.8
North and South Carolina	+1.3	+0.3	-0.1
Georgia	+0.7	+0.6	+1.2
Florida	+0.6	+0.5	+1.2
Ohio	+1.2	+4.2	+6.1
Michigan	+1.2	+0.8	+0.9
Indiana	-0.4	+2.3	+6.1
Illinois	-0.4	+0.3	+0.4
Wisconsin	+2.2	+4.1	+3.9
Kentucky	-3.2	+0.6	+2.3
Tennessee	-0.9	+1.1	+1.7
Alabama	+0.9	+0.8	-0.4
Mississippi	+2.3	+5.3	+4.6
Minnesota	-1.5	-1.5	+0.1
Iowa	+0.1	+1.6	+1.2
Missouri	-0.3	+2.6	+3.4
Arkansas	+0.6	+1.0	+0.6
Louisiana	-0.1	+0.1	-0.1

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[a] A 1980 rate base is used to compute changes in percentage terms.

TABLE 10

REGIONAL COAL PRODUCTION: AHR CASE[a]
(million tons)

Region	1980	Forecast 1985	1990	1995	Change from 1980 1985	1990	1995
Northern Appalachia	185	175	170	181	-10	-15	-4
Central Appalachia	233	272	320	338	39	87	105
Southern Appalachia	26	32	29	26	6	3	-
Total, Appalachia[b]	444	478	520	545	34	76	101
Midwest	134	108	103	101	-26	-31	-33
Eastern Northern Great Plains	17	23	32	32	6	15	15
Western Northern Great Plains	125	169	219	260	44	94	135
Total, Northern Great Plains[b]	142	193	251	292	51	109	150
Central West	13	14	18	23	1	5	10
Gulf	29	39	87	126	10	58	97
Rockies	32	47	74	111	15	42	79
Southwest	29	38	58	81	9	29	52
Northwest	5	5	5	6	-	-	1
Alaska	1	4	10	12	3	9	11
Total, Rest of West[b]	109	147	252	360	38	143	251
Total, United States[b]	830	925	1,125	1,298	95	295	468

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[a] Regional details in Attachment A-1.

[b] Totals may not add due to independent rounding.

TABLE 11

REGIONAL COAL PRODUCTION: BASE CASE[a]
(million tons)

Region	1980	Forecast 1985	1990	1995	Change from 1980 1985	1990	1995
Northern Appalachia	185	183	195	213	-2	10	28
Central Appalachia	233	253	276	295	20	43	62
Southern Appalachia	26	32	29	26	6	3	-
Total, Appalachia[b]	444	467	500	534	23	56	90
Midwest	134	130	158	182	-4	24	48
Eastern Northern Great Plains	17	23	32	33	6	15	16
Western Northern Great Plains	125	168	211	250	43	86	125
Total, Northern Great Plains[b]	142	191	243	283	49	101	141
Central West	13	15	24	23	2	11	10
Gulf	29	39	87	126	10	58	97
Rockies	32	40	54	73	8	22	41
Southwest	29	37	48	61	8	19	32
Northwest	5	5	5	6	-	-	1
Alaska	1	4	10	12	3	9	11
Total, Rest of West[b]	109	139	227	302	30	118	193
Total, United States[b]	830	927	1,127	1,300	97	297	470

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[a] Regional details in Attachment A-2.

[b] Totals may not add due to independent rounding.

TABLE 12

REGIONAL COAL PRODUCTION BY SULFUR CONTENT
(mmtons/year)

	1980	1985 ANR Case	1985 Changes from Base	1990 ANR Case	1990 Changes from Base	1995 ANR Case	1995 Changes from Base
Northern Appalachia							
Metallurgical	34.1	29.3	+1.3	33.4	+1.5	34.1	+0.5
Low Sulfur	0.3	0.7	+0.7	0.4	+0.1	0.1	+0.1
Medium Sulfur	54.9	76.8	-1.0	74.5	-11.1	84.2	-15.3
High Sulfur	95.8	68.4	-8.6	62.0	-15.4	62.5	-17.4
Total	185.1	175.2	-7.6	170.4	-24.9	180.9	-32.1
Central Appalachia							
Metallurgical	76.6	73.9	-1.6	74.7	-1.5	76.7	-0.4
Low Sulfur	16.1	40.7	+1.5	101.2	+36.7	128.1	+42.5
Medium Sulfur	131.9	154.5	+18.7	142.2	+9.4	132.1	+1.4
High Sulfur	8.2	2.4	-	1.7	-0.3	1.2	-0.1
Total	232.8	271.5	+18.6	319.9	+44.3	338.1	+43.4
Southern Appalachia							
Metallurgical	9.8	9.9	-	9.6	-0.3	9.3	-
Low Sulfur	1.1	3.0	-1.7	4.2	-1.6	4.6	-0.2
Medium Sulfur	15.5	18.8	+1.9	15.6	+2.8	11.5	-0.2
High Sulfur	-	-	-	-	-	-	-
Total	26.4	31.7	+0.2	29.4	+0.9	25.5	-0.4
Midwest							
Metallurgical	2.9	3.0	+0.3	2.2	-	1.3	-
Low Sulfur	0.1	-	-	-	-	-	-
Medium Sulfur	16.2	21.8	+2.1	26.5	+0.7	25.3	-1.1
High Sulfur	115.1	82.7	-24.6	74.1	-55.7	74.1	-80.1
Total	134.4	107.5	-22.2	102.8	-55.0	100.8	-81.2
Eastern Northern Great Plains							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	-	-	-	-	-	-	-
Medium Sulfur	17.3	23.3	-	31.7	-	32.1	-0.9
High Sulfur	-	-	-	-	-	-	-
Total	17.3	23.3	-	31.7	-	32.1	-0.9
Western Northern Great Plains							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	67.6	117.5	+3.6	151.1	+7.4	176.3	+9.8
Medium Sulfur	56.9	51.8	-1.8	67.8	+0.7	83.9	+0.8
High Sulfur	-	-	-	-	-	-	-
Total	124.5	169.3	+1.8	218.9	+8.1	260.3	+10.6

TABLE 12 (Continued)

REGIONAL COAL PRODUCTION BY SULFUR CONTENT
(mmtons/year)

		1985		1990		1995	
	1980	ANR Case	Changes from Base	ANR Case	Changes from Base	ANR Case	Changes from Base
Central West							
Metallurgical	0.7	0.8	+0.1	0.8	+0.1	0.9	-
Low Sulfur	0.2	0.9	+0.1	2.4	+0.6	2.3	-0.1
Medium Sulfur	0.7	2.0	+0.1	5.4	-0.4	8.1	+1.4
High Sulfur	11.0	10.4	-1.0	9.1	-6.2	11.9	-1.3
Total	12.6	14.1	-0.7	17.7	-5.9	23.2	-
Gulf							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	-	-	-	-	-	-	-
Medium Sulfur	29.4	38.6	-	86.6	-	121.1	-
High Sulfur	-	-	-	-	-	5.1	-
Total	29.4	38.6	-	86.6	-	126.2	-
Rocky Mountains							
Metallurgical	3.2	2.5	-0.1	2.7	+0.1	2.7	-0.1
Low Sulfur	24.6	36.2	+3.5	58.3	+14.9	90.3	+34.8
Medium Sulfur	4.3	7.8	+2.6	13.2	+4.9	18.1	+3.9
High Sulfur	-	-	-	-	-	-	-
Total	32.1	46.6	+6.0	74.3	+19.9	111.2	+38.6
Southwest							
Metallurgical	0.8	-	-	-	-	-	-
Low Sulfur	16.0	19.6	+1.3	31.6	+9.4	44.9	+13.4
Medium Sulfur	12.5	18.8	+0.4	26.7	+1.3	36.2	+6.4
High Sulfur	-	-	-	-	-	-	-
Total	29.3	38.4	+1.7	58.2	+10.7	81.1	+19.8
Northwest							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	-	-	-	-	-	-	-
Medium Sulfur	5.1	5.0	+0.3	5.1	-	6.3	-
High Sulfur	-	-	-	-	-	-	-
Total	5.1	5.0	+0.3	5.1	-	6.3	-
Alaska							
Metallurgical	-	-	-	-	-	-	-
Low Sulfur	0.8	3.9	-	10.1	-	12.3	-
Medium Sulfur	-	-	-	-	-	-	-
High Sulfur	-	-	-	-	-	-	-
Total	0.8	3.9	-	10.1	-	12.3	-
Total U.S.							
Metallurgical	127.8	119.5	-	123.5	-0.1	125.1	-
Low Sulfur	126.2	222.5	+9.0	359.4	+67.5	459.0	+100.3
Medium Sulfur	341.6	419.2	+23.3	495.3	+8.3	559.0	-3.6
High Sulfur	234.1	163.9	-34.2	146.9	-77.6	154.9	-98.9
Total	829.7	925.1	-1.9	1,125.1	-1.9	1,298.0	-2.2

TABLE 13

SHIFTS IN COAL MINING AND TRANSPORTATION EMPLOYMENT: ANR CASE

	Average Number of Workers in 1980 (10^3 workers)	Change in Employment from 1980 (10^3 workers) 1985 ANR Case	1990 ANR Case	1995 ANR Case
A. COAL MINING[a]				
Northern Appalachia	69	-1	+2	+10
Central Appalachia	93	+22	+49	+62
Southern Appalachia	11	+3	+3	+3
Total, Appalachia[c]	173	+25	+53	+75
Midwest	35	-6	-6	-6
Eastern Northern Great Plains	2	+1	+1	+1
Western Northern Great Plains	6	+2	+6	+8
Total, Northern Great Plains[c]	8	+3	+7	+10
Central West	3	+1	+3	+5
Gulf	2	+1	+5	+10
Rockies	7	+5	+10	+18
Southwest	2	+1	+5	+9
Northwest	1	-	-	-
Alaska	-	-	+1	+1
Total, Rest of West[c]	15	+7	+24	+43
Total U.S.[c]	231	+28	+77	+121
B. COAL TRANSPORTATION[b]				
Transportation Employment	15	+3	+7	+13
C. TOTAL, MINING AND TRANSPORTATION				
Coal Mining	231	+28	+77	+121
Transportation	15	+3	+7	+13
Total[c]	246	+31	+84	+134

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[a] Details in Attachment A-1.

[b] Details in Attachment A-3.

[c] Totals may not add due to independent rounding.

TABLE 14

SHIFTS IN COAL MINING AND TRANSPORTATION EMPLOYMENT:
EPA BASE CASE

	Average Number of Workers in 1980 (10^3 workers)	Change in Employment from 1980 (10^3 workers)		
		1985 Base Case	1990 Base Case	1995 Base Case
A. COAL MINING[a]				
Northern Appalachia	69	+2	+11	+25
Central Appalachia	93	+15	+28	+41
Southern Appalachia	11	+3	+3	+3
Total, Appalachia[c]	173	+20	+42	+69
Midwest	35	-1	+8	+17
Eastern Northern Great Plains	2	+1	+1	+1
Western Northern Great Plains	6	+2	+4	+7
Total, Northern Great Plains[c]	8	+3	+5	+8
Central West	3	+1	+4	+5
Gulf	2	+1	+5	+10
Rockies	7	+3	+6	+10
Southwest	2	-	+2	+4
Northwest	1	-	-	-0
Alaska	-	-	+1	+1
Total, Rest of West[c]	15	+5	+18	+30
Total U.S.[c]	231	+27	+74	+124
B. COAL TRANSPORTATION[b]				
Transportation Employment	15	+3	+7	+11
C. TOTAL, MINING AND TRANSPORTATION				
Coal Mining	231	+27	+74	+124
Transportation	14	+3	+7	+11
Total	246	+30	+81	+135

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a/ Details in Attachment A-2.

b/ Details in Attachment A-4.

c/ Totals may not add due to independent rounding.

ESTIMATED COAL PRODUCTION AND COAL MINING EMPLOYMENT: ANR CASE

Supply Region	Production (10^6 tons) 1980	Production (10^6 tons) 1985 ANR Case	Production (10^6 tons) 1990 ANR Case	Production (10^6 tons) 1995 ANR Case	Average Number of Workers (10^3 workers) 1980	Average Number of Workers (10^3 workers) 1985 ANR Case	Average Number of Workers (10^3 workers) 1990 ANR Case	Average Number of Workers (10^3 workers) 1995 ANR Case	Employment Change from 1980 (10^3 workers) 1985 ANR Case	Employment Change from 1980 (10^3 workers) 1990 ANR Case	Employment Change from 1980 (10^3 workers) 1995 ANR Case
Northern Appalachia											
PC	61.4	63.1	56.0	51.0	22.1	24.1	23.4	23.8	+2.0	+1.3	+1.8
PW	31.7	35.5	40.3	46.3	13.9	16.8	19.7	22.7	+2.9	+5.8	+8.8
OH	39.4	30.3	24.5	33.7	14.7	11.3	9.1	12.2	-3.4	-5.6	-2.5
MD	3.8	4.0	3.2	2.9	1.1	1.2	1.0	1.2	+0.1	-0.1	+0.1
WN	48.8	42.4	46.4	47.0	17.2	15.1	17.3	19.5	-2.1	-	+2.2
Total	185.1	175.3	170.4	180.9	69.1	68.5	70.6	79.4	-0.6	+1.5	+10.3
Central Appalachia											
WS	72.7	88.4	134.8	160.6	36.9	49.0	69.5	82.3	+12.1	+32.6	+45.4
VA	41.0	49.4	52.0	45.6	16.1	20.3	22.9	20.9	+4.2	+6.8	+4.8
KE	109.3	123.1	122.2	121.1	35.7	41.2	44.1	46.5	+5.5	+8.4	+10.8
TN	9.9	10.6	10.9	10.7	3.9	4.3	4.6	4.6	+0.4	+0.7	+0.7
Total	232.8	271.5	319.9	338.1	92.6	114.8	141.1	154.3	+22.2	+48.5	+61.7
Southern Appalachia											
AL	26.4	31.7	29.4	25.5	11.4	14.5	14.3	14.1	+3.1	+2.9	+2.7
Total	26.4	31.7	29.4	25.5	11.4	14.5	14.3	14.1	+3.1	+2.9	+2.7
TOTAL APPALACHIA	444.3	478.4	519.7	544.5	173.1	197.8	226.0	247.8	+24.7	+52.9	+74.7
Midwest											
IL	62.5	43.0	40.6	30.6	17.0	12.6	11.0	8.7	-5.2	-6.0	-8.3
IN	30.9	26.3	28.1	33.0	5.3	6.4	7.0	9.7	-0.9	+1.7	+4.4
WK	41.0	38.2	34.2	37.2	12.8	11.6	10.4	10.5	-0.4	-1.7	-1.3
Total	134.4	107.5	102.9	100.8	35.1	30.7	29.1	28.9	-4.4	-6.0	-6.2
TOTAL MIDWEST	134.4	107.5	102.9	100.8	35.1	30.7	29.1	28.9	-4.4	-6.0	-6.2
Eastern Northern Great Plains											
ND	17.0	23.1	31.5	31.9	1.7	2.3	2.9	2.9	+0.6	+1.2	+1.2
SD	0.3	0.2	0.2	0.2	-	-	-	-	-	-	-
Total	17.3	23.3	31.7	32.1	1.7	2.3	2.9	2.9	+0.6	+1.2	+1.2
Western Northern Great Plains											
MM	-	0.8	1.3	1.7	-	0.2	0.3	0.4	+0.2	+0.3	+0.4
MP	29.6	39.1	49.9	72.0	1.1	1.5	1.8	2.6	+0.4	+0.7	+1.5
WP	68.8	100.2	122.3	129.2	2.0	2.9	3.6	3.8	+0.9	+1.6	+1.8
WG	26.1	29.3	45.3	57.3	2.9	3.3	5.7	7.3	+0.4	+2.8	+4.4
Total	124.5	169.3	218.9	260.3	6.0	7.8	11.5	14.3	+1.9	+5.5	+8.3
TOTAL NORTHERN GREAT PLAINS	141.7	192.6	250.6	292.4	7.7	10.2	14.4	17.3	+2.5	+6.7	+9.5

ESTIMATED COAL PRODUCTION AND COAL MINING EMPLOYMENT: AHR CASE

Supply Region		Production (10^6 tons) 1980	1985 AHR Case	1990 AHR Case	1995 AHR Case	Average Number of Workers (10^3 workers) 1980	1985 AHR Case	1990 AHR Case	1995 AHR Case	Employment Change from 1980 (10^3 workers) 1985 AHR Case	1990 AHR Case	1995 AHR Case
Central West												
	IA	0.6	0.6	0.5	1.0	0.1	0.2	0.1	0.3	-	-	+0.2
	MO	5.5	4.6	4.0	6.3	1.1	0.9	0.8	1.6	-0.2	-0.3	+0.5
	KS	0.6	2.3	1.7	2.6	0.3	0.6	0.5	0.8	+0.4	+0.2	+0.6
	AR	0.3	1.6	4.7	7.0	0.1	0.7	2.2	3.3	+0.6	+2.0	+3.1
	OK	5.4	5.0	6.8	6.4	1.3	1.3	2.1	2.2	-	+0.8	+0.9
Total		12.6	14.3	17.7	23.2	2.9	3.7	5.7	8.3	+0.8	+2.8	+5.3
Gulf												
	TX	29.4	38.6	77.0	104.8	1.7	2.4	5.9	8.9	+0.7	+4.2	+7.2
	LA	-	-	8.8	16.5	-	-	1.0	1.9	-	+1.0	+1.9
	AR	-	-	-	5.0	-	-	-	0.5	-	-	+0.5
Total		29.4	38.6	86.6	126.3	1.7	2.4	7.0	11.3	+0.7	+5.2	+9.6
Rockies												
	CO	13.7	15.2	30.1	41.6	1.7	1.9	3.8	6.2	-0.2	+2.1	+4.5
	CD	0.4	0.7	0.8	0.7	0.2	0.3	0.4	0.4	-0.2	+0.2	+0.2
	CR	0.9	3.3	7.9	11.2	0.4	1.4	2.8	3.8	+1.0	+2.4	+3.4
	CU	3.8	8.5	12.1	23.2	1.4	3.1	4.1	6.7	+1.7	+2.7	+5.4
	CS	0.1	-	1.5	2.1	-	-	0.2	0.3	-	+0.2	+0.2
	UC	13.2	18.9	22.1	30.5	3.5	5.0	5.8	7.8	+1.5	+2.3	+4.2
	US	-	-	1.0	1.8	-	-	0.2	0.2	-	+0.2	+0.2
Total		32.1	46.6	74.3	111.2	7.2	11.8	17.2	25.3	+4.6	+10.1	+18.0
Southwest												
	AZ	10.9	12.0	13.2	19.7	0.9	1.0	1.0	1.8	+0.1	+0.1	+0.9
	NR	1.9	2.7	11.2	16.4	0.6	0.8	3.7	5.7	+0.2	+3.1	+5.1
	NS	16.6	23.7	34.0	45.0	1.0	1.5	2.5	3.6	+0.5	+1.5	+2.6
Total		29.3	38.4	58.2	81.1	2.5	3.3	7.2	11.1	+0.8	+4.7	+8.6
Northwest												
	WA	5.1	5.0	5.1	6.3	0.6	0.6	0.6	0.9	-	+0.1	+0.3
Total		5.1	5.0	5.1	6.3	0.6	0.6	0.6	0.9	-	+0.1	+0.3
Alaska												
	AK	0.8	3.9	10.1	12.3	-	0.2	0.7	1.0	+0.2	+0.7	+1.0
Total		0.8	3.9	10.1	12.3	-	0.2	0.7	1.0	+0.2	+0.7	+1.0
TOTAL WEST		109.3	146.6	252.0	360.3	15.1	22.1	38.6	57.9	+7.0	+23.5	+42.8
TOTAL UNITED STATES		829.7	925.1	1,125.1	1,290.0	231.0	258.0	308.1	351.0	+27.0	+77.1	+120.0

Note: Totals may not add due to independent rounding.

ICF INCORPORATED

ATTACHMENT A-2

ESTIMATED COAL PRODUCTION AND COAL MINING EMPLOYMENT: BASE CASE

Supply Region	Production (10^6 tons)				Average Number of Workers (10^3 workers)				Employment Change from 1980 (10^3 workers)		
	1980	1985 Base Case	1990 Base Case	1995 Base Case	1980	1985 Base Case	1990 Base Case	1995 Base Case	1985 Base Case	1990 Base Case	1995 Base Case
Northern Appalachia											
PC	61.4	62.0	63.4	56.8	22.1	23.5	26.9	26.7	+1.4	+4.7	+4.5
PW	31.7	30.3	45.4	57.9	13.9	18.0	22.1	28.5	+4.1	+8.2	+14.6
OH	39.4	36.1	30.9	41.2	14.7	12.8	12.6	15.0	-1.9	-2.1	+0.3
MD	3.0	8.0	8.3	2.9	1.1	1.2	1.6	1.2	+0.1	+0.5	+0.1
WN	49.6	46.2	47.4	54.2	17.3	15.7	17.4	22.2	-1.6	+0.1	+4.9
Total	185.1	182.8	195.4	213.0	69.1	71.2	80.6	93.7	+2.1	+11.4	+24.5
Central Appalachia											
WS	72.7	83.6	109.5	135.4	36.9	46.8	57.5	70.0	+9.9	+20.5	+33.1
VA	41.0	47.6	47.3	42.7	16.0	(19.9)	20.7	19.2	+3.9	+4.7	+3.1
KE	109.2	111.4	109.5	106.9	35.7	37.1	38.0	40.4	+1.4	+2.3	+4.7
TN	9.9	10.2	9.3	9.8	3.9	4.1	3.8	4.3	+0.2	-	+0.4
Total	232.8	252.8	275.6	294.8	92.5	107.9	120.0	133.9	+15.3	+27.5	+41.3
Southern Appalachia											
AL	26.4	31.5	20.5	25.9	11.4	14.4	14.5	14.3	+3.0	+3.1	+2.9
Total	26.4	31.5	20.5	25.9	11.4	14.4	14.5	14.3	+3.0	+3.1	+2.9
TOTAL APPALACHIA	444.3	467.1	491.5	533.6	173.0	193.5	215.1	241.9	+20.5	+42.0	+68.7
Midwest											
IL	62.5	62.3	58.7	72.5	17.8	17.7	16.8	20.5	-0.1	-0.9	+2.8
IN	30.9	29.9	40.0	46.9	5.3	5.3	10.1	14.0	-	+4.8	+8.7
KW	41.0	37.4	39.1	62.6	12.0	11.0	16.5	17.6	-1.0	+4.4	+5.5
Total	134.4	129.6	137.8	182.0	35.1	34.0	43.4	52.1	-1.1	+8.3	+17.0
TOTAL MIDWEST	134.4	129.6	137.8	182.0	35.1	34.0	43.4	52.1	-1.1	+8.3	+17.0
Eastern Northern Great Plains											
ND	17.0	23.1	31.5	32.7	1.7	2.3	2.9	3.0	+0.6	+1.2	+1.3
SD	0.3	0.2	0.2	0.2	-	-	-	-	-	-	-
Total	17.3	23.3	31.7	33.0	1.7	2.3	2.9	3.0	+0.6	+1.2	+1.3
Western Northern Great Plains											
NW	-	0.8	1.3	1.7	-	1.6	0.3	0.4	+1.6	+0.3	+0.4
MP	29.6	41.2	51.5	69.1	1.1	0.2	1.9	2.5	-0.9	+0.8	+1.4
WP	68.8	95.1	122.1	129.0	2.0	2.8	3.6	3.0	+0.8	+1.6	+1.0
WG	26.1	29.6	35.2	49.9	2.8	3.1	4.2	6.0	+0.3	+1.4	+3.2
Total	124.5	166.7	210.8	249.7	5.9	7.7	10.0	12.0	+1.8	+4.1	+6.0
TOTAL NORTHERN GREAT PLAINS	141.7	190.0	243.5	282.6	7.6	10.1	12.9	15.0	+2.5	+5.3	+7.4

ESTIMATED COAL PRODUCTION AND COAL MINING EMPLOYMENT: BASE CASE

Supply Region		Production (10^6 tons) 1980	1985 Base Case	1990 Base Case	1995 Base Case	Average Number of Workers (10^3 workers) 1980	1985 Base Case	1990 Base Case	1995 Base Case	Employment Change from 1980 (10^3 workers) 1985 Base Case	1990 Base Case	1995 Base Case
Central West												
	IA	0.6	0.6	0.9	1.0	0.1	0.2	0.3	0.3	+0.1	+0.1	+0.2
	MO	5.5	5.1	8.4	6.9	1.1	1.1	2.0	1.8	-	+0.9	+0.7
	KS	0.8	2.7	2.8	3.2	0.2	0.8	0.9	1.1	+0.6	+0.7	+0.9
	AR	0.3	1.4	5.3	5.8	0.1	0.6	2.5	2.7	+0.5	+2.3	+2.5
	OK	5.4	5.1	6.1	6.3	1.3	1.3	1.7	2.2	-	+0.4	+0.9
Total		12.6	14.9	23.5	23.3	2.8	3.9	7.4	8.1	+1.1	+4.6	+5.2
Gulf												
	TX	29.4	38.6	77.8	106.8	1.7	2.4	6.0	8.9	+0.7	+4.2	+7.2
	LA	-	-	8.8	14.5	-	-	1.0	1.9	-	+1.0	+1.9
	AS	-	-	-	5.0	-	-	-	0.5	-	-	+0.5
Total		29.4	38.6	86.6	126.2	1.7	2.4	7.0	11.3	+0.7	+5.2	+9.6
Rockies												
	CO	13.7	12.9	16.5	19.7	1.7	1.6	2.0	2.4	-0.1	+0.3	+0.7
	CD	0.4	0.7	0.6	0.6	0.2	0.3	0.3	0.3	+0.1	+0.1	+0.1
	CR	0.9	2.0	3.7	7.7	0.4	1.0	1.5	2.7	+0.6	+1.1	+2.3
	CU	3.8	5.3	9.0	10.2	1.4	2.0	3.3	3.4	+0.6	+1.9	+2.0
	CS	0.1	-	-	1.1	-	-	-	0.2	-	-	+0.1
	UC	13.3	19.6	23.9	32.4	3.5	5.2	6.3	8.2	+1.7	+2.8	+4.7
	US	-	-	-	0.8	-	-	-	-	-	-	-
Total		32.1	40.5	54.4	72.5	7.2	10.1	13.4	17.2	+2.9	+6.2	+10.1
Southwest												
	AS	10.9	12.0	13.5	16.6	0.9	1.0	1.1	1.4	+0.1	+0.2	+0.5
	NR	1.9	1.9	3.1	7.1	0.6	0.6	0.9	2.3	-	+0.3	+1.7
	NM	16.4	22.8	30.9	37.6	1.0	1.4	2.1	2.8	+0.4	+1.0	+1.8
Total		29.3	36.7	47.5	61.3	2.5	3.0	4.1	6.5	+0.5	+1.5	+4.0
Northwest												
	WA	5.1	4.7	5.1	6.3	0.6	0.6	0.6	0.9	-	-	+0.3
Total		5.1	4.7	5.1	6.3	0.6	0.6	0.6	0.9	-	-	+0.3
Alaska												
	AK	0.8	3.9	10.1	13.3	-	0.2	0.8	1.0	+0.2	+0.7	+1.0
Total		0.8	3.9	10.1	13.3	-	0.2	0.8	1.0	+0.2	+0.7	+1.0
TOTAL WEST		109.3	139.3	227.2	301.9	14.8	20.2	33.3	45.1	+5.4	+18.0	+30.0
TOTAL UNITED STATES		839.7	926.0	1,127.0	1,300.1	230.5	257.8	304.7	354.0	+27.3	+73.6	+123.8

Note: Totals may not add due to independent rounding.

ATTACHMENT A-3

ESTIMATED COAL TRANSPORTATION TON-MILES AND EMPLOYMENT: ANR CASE

	Ton-Miles ($x\ 10^9$)				Average Number of Workers a/ (10^3 workers)				Employment Change from 1980 a/ (10^3 workers)		
	1980	1985	1990	1995	1980 b/	1985	1990	1995	1985	1990	1995
Mode											
Rail	N/A	325.3	426.5	529.4	6.1	7.7	10.2	12.9	+1.6	+4.1	+6.8
Barge/Lake c/	N/A	36.6	56.4	60.2	1.3	1.1	1.7	1.8	-0.2	+0.4	+0.5
Truck	N/A	7.0	8.0	10.1	5.1	5.7	6.6	8.7	+0.6	+1.5	+3.6
Other d/	N/A	360.3	506.4	646.1	2.0	2.4	3.3	4.2	+0.4	+1.3	+2.2
Total e/		729.2	997.3	1,245.7	14.5	17.0	21.8	27.5	+2.5	+7.3	+13.0

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a/ Because the methodology focuses upon those workers directly involved in the movement of coal, total transportation employment requirements are likely to be underestimated.

b/ ICF estimates for 1980 employment were developed by applying forecasted transportation productivity (by origin-destination and mode of transport) to actual 1980 coal flows.

c/ Over many origin-destination routes, rail barge and all rail movements exist. In CEUM, these are generally represented as all-rail. As a result, forecasted barge movements are likely to be understated, and rail movements overstated by a similar amount.

d/ Mostly ocean transportation for exports.

e/ Totals may not add due to independent rounding.

ATTACHMENT A-4

ESTIMATED COAL TRANSPORTATION TON-MILES AND EMPLOYMENT: BASE CASE

	Ton-Miles (x 10^9)				Average Number of Workers[a] (10^3 workers)				Employment Change from 1980[a] (10^3 workers)		
Mode	1980	1985	1990	1995	1980[b]	1985	1990	1995	1985	1990	1995
Rail	N/A	314.9	387.4	462.2	6.1	7.6	9.5	11.6	+1.5	+3.4	+5.5
Barge/Lake[c]	N/A	43.9	67.3	68.5	1.3	1.4	1.9	2.0	+0.1	+0.6	+0.7
Truck	N/A	7.1	6.4	9.5	5.1	5.7	6.7	7.4	+0.6	+1.6	+2.3
Other[d]	N/A	359.9	506.5	644.8	2.0	2.4	3.3	4.2	+0.4	+1.3	+2.2
Total[e]		725.8	969.6	1,185.0	14.5	17.1	21.5	25.2	+2.6	+7.0	+10.7

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[a] Because the methodology focuses upon those workers directly involved in the movement of coal, total transportation employment requirements are likely to be underestimated.

[b] ICF estimates for 1980 employment were developed by applying forecasted transportation productivity (by origin-destination and mode of transport) to actual 1980 coal flows.

[c] Over many origin-dentination routes, rail barge and all rail movements exist. In CEUM, these are generally represented as all-rail. As a result, forecasted barge movements are likely to be understated, and rail movements overstated by a similar amount.

[d] Mostly ocean transportation for exports.

[e] Totals may not add due to independent rounding.

Exhibit 4

SCRUBBING COSTS FOR AN ILLINOIS BASIN COAL

The following information is provided on: (1) average size of new and existing coal-fired generating plants; (2) capital costs of a flue gas desulfurization (FGD) unit for an Illinois Basin coal; and (3) the operating costs associated with FGD operation. All of the quoted cost information is related to the scrubbing of a 22 million Btu/ton Illinois Basin coal with 3.5% sulfur.

Analysis

A. Average Size of New and Existing Coal Plants

As the attached tables demonstrate, coal-fired units in the 501-550 MW capacity class comprise the largest share of total coal generating capacity for both existing and new units. For purposes of the cost information discussed below, a 500 KW coal plant is used.

A 500 MW coal plant that burns 22 MMBtu/ton Illinois Basin coal will consume 1.1-1.2 million tons of coal annually under normal baseload operating conditions (60% load factor).

B. Capital Costs of FGD

According to DOE estimates[1], the capital cost of a scrubber is $122/KW of capacity (1982$) for a system that would remove 90% of the sulfur in an Illinois Basin coal or $61.0 million dollars for a 500 MW coal plant at a coal consumption rate of 1.2 million tons per year the capital cost of scrubbing amounts to $7.50/ton.

C. Annualized Operating Costs of FGD

The fixed and variable operating costs for a scrubber on a 3.5% sulfur coal is 4.63 Mills./KWH or $9.38/ton of coal processed.[2] This cost includes the fixed charges of operating labor, supervision and administration and the variable charges of maintenance material, electricity for FGD, waste disposal charges and all other activity level dependent SO_2 removal costs.

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[1] A Guide for the Assessment of Technologies for Generating Electricity, DOE, June 1982.

[2] Acid Rain Boiler Population Analysis, PEDCO Environmental Inc., April 1983.

D. Total Annual Costs of Pollution Control

The total annualized cost of installing FGD is 8.0 Mills./KWH of electricity generated or an increase of 11.7% to existing residential customers. The total cost is comprised of the 4.63 Mills./KWH for the variable costs previously discussed and a charge of 3.4 Mills./KWH for recovery of the capital costs of the scrubber. The capital recovery charge for the scrubber is based on a 15 year economic life, a before tax average cost of capital to utilities of 12.0%, current tax laws and effective utility tax rates.

The annual capital charge for the scrubber is $8.9 million and the related annual operating charges of $12.2 million. The total annual charges of $21.1 million would be recovered from the 2,628 million KWH of sales generated by the 500 MW coal-fired plant. Thus, the total cost of scrubbing is about $16/ton in 1982 dollars.

Table 12. U.S. Coal Units by Capacity Class in 1980
(Total Units = 1,254; Total MW = 239,940)

Capacity (MW)	Number of Units	Percentage of Total Units	Generating Capacity (MW)	Percentage of Total Generating Capacity
0 - 50	406	0.32	7,532	0.03
51 - 100	187	0.15	13,777	0.06
101 - 150	156	0.12	19,095	0.08
151 - 200	114	0.09	19,370	0.08
201 - 250	72	0.06	15,862	0.07
251 - 300	43	0.03	11,573	0.05
301 - 350	38	0.03	12,318	0.05
351 - 400	31	0.02	11,337	0.05
401 - 450	19	0.02	7,906	0.03
451 - 500	19	0.02	8,842	0.04
501 - 550	41	0.03	21,205	0.09
551 - 600	27	0.02	15,372	0.06
601 - 650	25	0.02	15,478	0.06
651 - 700	23	0.02	15,107	0.06
701 - 750	11	0.01	7,859	0.03
751 - 800	13	0.01	9,875	0.04
801 - 850	11	0.01	8,948	0.04
≥ 851	18	0.01	18,484	0.08

Source: Reference 6.

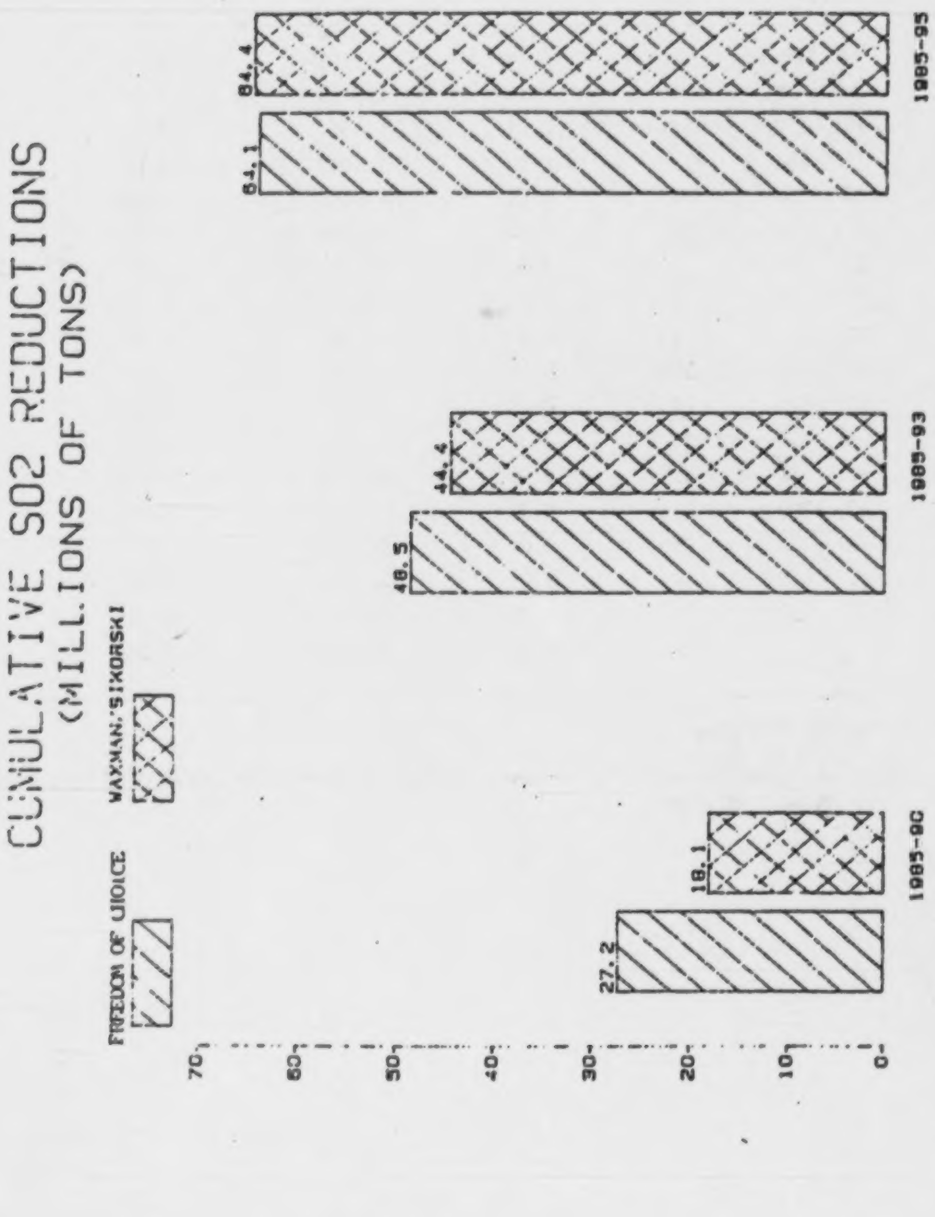
Table 13. U.S. Coal Units by Capacity Class in 1985*
(Total Units = 1,360; Total MW = 306,992)

Capacity (MW)	Number of Units	Percentage of Total Units	Generating Capacity (MW)	Percentage of Total Generating Capacity
0 - 50	387	0.28	7,015	0.02
51 - 100	185	0.14	13,678	0.04
101 - 150	156	0.11	19,061	0.06
151 - 200	116.	0.09	19,680	0.06
201 - 250	78	0.06	17,186	0.06
251 - 300	51	0.04	13,658	0.04
301 - 350	47	0.03	15,260	0.05
351 - 400	35	0.03	12,849	0.04
401 - 450	32	0.02	13,150	0.04
451 - 500	24	0.02	11,258	0.04
501 - 550	68	0.05	39,139	0.11
551 - 600	30	0.02	17,078	0.06
601 - 650	42	0.03	25,928	0.08
651 - 700	33	0.02	21,782	0.07
701 - 750	19	0.01	13,499	0.04
751 - 800	16	0.01	12,166	0.04
801 - 850	19	0.01	15,371	0.05
≥ 851	22	0.02	23,234	0.08

Source: Reference 6.

* Including utility announcements. Subject to changes in actual 1980-1985 capacity additions.

EXHIBIT 5A


CUMULATIVE SO2 REDUCTIONS
(MILLIONS OF TONS)
FREEDOM OF CHOICE
WAXMAN/SIKORSKI
70
60
50
40
30
20
10
0
27.2
18.1
48.5
44.4
64.1
64.4
1985-90
1985-93
1985-95

EXPECTED ANNUAL SO_2 REDUCTIONS
(Millions of Tons)

	SIKORSKI/WAXMAN [1]	FREEDOM OF CHOICE [2]
1985	1.3	3.0
1986	1.3	3.5
1987	1.3	4.0
1988	2.9	4.7
1989	4.7	5.5
1990	6.6	6.5
1991	7.6	6.8
1992	8.7	7.1
1993	10.0	7.4
1994	10.0	7.7
1995	10.0	7.9

CUMULATIVE SO_2 REDUCTIONS
(Millions of Tons)

	SIKORSKI/WAXMAN [1]	FREEDOM OF CHOICE [2]
1985-90	18.1	27.2
1985-93	44.4	48.5
1985-95	64.4	64.1

SOURCES:

1/ ANR Analysis of H. R. 3400
2/ Exhibit 3

Mining jobs and acid rain

Cost-effective equivalent of H.R. 3400

In a September 1983 study prepared for the Alliance for Clean Energy, ICF, Inc. compared H.R. 3400 (the Waxman Sikorski Acid Rain bill) with a cost-effective program that would produce equivalent reductions in sulfur dioxide emissions. ICF concluded that the cost-effective equivalent will have little effect on mining employment . The study found:

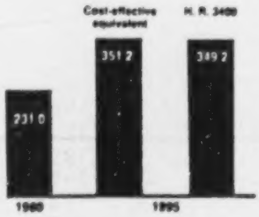
- **Coal mining employment goes up 52% over 1980 levels**—this creates 120,200 new mining jobs.
- **21 coal producing states both East and West gain 138,100 jobs by 1995.**
- **Employment declines in 4 states**—but 98% of the declines are in just 2 states (Ohio and Illinois).
- **Cost-effective acid rain controls actually add new jobs to several states**—*e.g.*, West Virginia gains 11,000 more.

The study also found that H.R. 3400, which is intended to protect high-sulfur coal markets, would cost consumers and taxpayers enormous sums. Protecting high-sulfur coal producers by requiring mandatory scrubbers would cause these results:

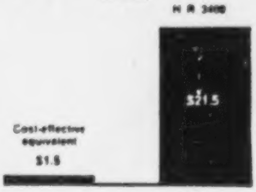
- **Capital costs increase fourteenfold** to $21.5 billion by 1995.
- **Annual costs will be 46% greater.**
- **Total mining employment will probably be lower under H.R. 3400**—than under the cost-effective equivalent.
- **Requiring scrubbers produces no net gains in environmental benefits despite the huge increase in costs.**

Acid rain controls

Total coal mining employment
(Thousands)



Cumulative capital costs in 1995
(Billions)



Changes in coal mining employment: 1980-1995 – Cost effective equivalent of H.R. 3400

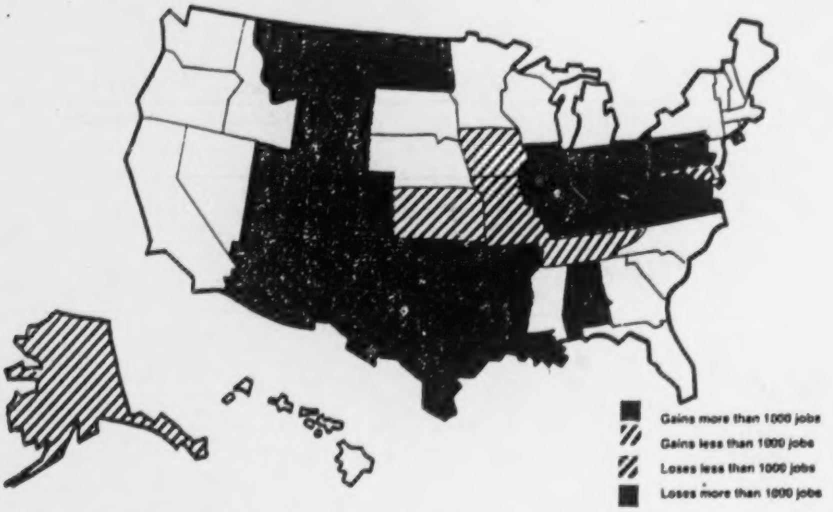

Gains more than 1000 jobs
Gains less than 1000 jobs
Loses less than 1000 jobs
Loses more than 1000 jobs

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EXHIBIT 6B

COAL MINING EMPLOYMENT CHANGES FROM 1980 — FREEDOM OF CHOICE
(Number of Workers)

	1980 Actual	1985	1990	1995
Northern App.	90,408	+15,690	+40,490	+59,090
Pennsylvania	35,918	+4,980	+7,180	+10,580
Maryland	1,087	+10	+90	+110
West Virginia	53,403	+10,700	+33,400	+48,400
Central and Southern App.	77,574	+14,320	+18,730	+19,030
Virginia	15,876	+4,420	+7,020	+5,020
Kentucky	46,395	+6,400	+8,110	+10,610
Tennessee	3,615	+690	+990	+990
Alabama	11,688	+2,810	+2,610	+2,410
Midwest	37,688	-9,400	-9,790	-7,090
Illinois	17,735	-5,140	-5,940	-9,040
Indiana	5,315	-920	+1,690	+4,390
Ohio	14,638	-3,340	-5,540	-2,440
West	22,899	+9,400	+30,100	+52,200
Total U.S.	228,569	+30,010	+79,530	+123,230

SOURCE: ICF, Inc. Oct. 4, 1983: Coal and Electric Utility Market Impacts of ANR's Proposed Phased Reduction Proposal for Reducing Sulfur Dioxide Emissions.

Coal Mining Employment

This analysis also incorporates an improved methodology for estimating employment changes in coal mining. Previous analyses of coal mining employment have relied upon use of historic productivity estimates applied to forecasted regional coal production.

However, the average productivity in 1980 includes production from many metallurgical coal mines which typically have lower productivity than those mines producing steam coals for the industrial and utility markets. Growth in coal demand, as well as shifts resulting from acid rain legislation, will be concentrated in steam coal production. Accordingly, in regions where metallurgical coal production is substantial, use of historic productivity estimates will tend to understate future productivity, overstate future employment levels, and exaggerate shifts (both gains and losses) in mining employment across the scenarios. Further, future productivity in a region could change from historic productivity as a result of changes in the proportion of surface and deep-mined coal, changes in mining technologies, changes in labor practices, and changes resulting from depletion of the more efficient mines.

In recognition of these problems inherent with the use of historic productivity values, we have undertaken the development of an improved methodology for estimating coal mining employment. Specifically, this methodology incorporates the same estimates of coal mining productivity that are used in ICF's Coal and Electric Utilities Model (CEUM) to forecast regional coal production and utility fuel use. In CEUM, coal supply is represented in the form of coal supply curves. There are over 200 coal supply curves, one for each type of coal in each of 40 coal supply regions. Each supply curve is represented as a step function, where each step represents a different type of mine (in terms of mine size, seam thickness, overburden ratio, and other factors). In developing the minimum acceptable selling price for each mine-type on each coal supply curve, the mine costing program in CEUM develops an estimate of productivity in terms of tons per man-day. Using these productivity estimates, we estimated the number of workers associated with the forecasted coal production of any given coal-type and region. In so doing, this improved methodology is able to circumvent many of the problems inherent in the use of historic productivity values.

Source: ICF Inc., Sept. 22, 1983, An Analysis of Coal Production and Employment Impacts of the Waxman/Sikorski Bill and a Cost-Effective Equivalent.

Senator WARNER. Thank you very much.

Mr. Bagge, you and I have discussed this subject on a number of occasions, and I purposely scheduled you to be the final and the wrap-up witness.

STATEMENT OF CARL E. BAGGE, PRESIDENT, NATIONAL COAL ASSOCIATION

Mr. BAGGE. Thank you; I'm honored, Senator. I just hope the constraints of time won't deny me the opportunity to tell you again what madness this legislation is.

I have to say, Senator, that I'm very indebted, not as a coal advocate, but as a concerned citizen of America that John Quarles—I sat here all day, and the only person who has raised the question that I tried to raise in the hearings at the Senate side, before the Environment Committee on the House side, the only person—and including administration witnesses this morning, not one of them pointed out the ultimate madness of this bill to shut down the American economy. And it's as simple as that.

I think that Mr. Quarles has documented it. I'm very grateful. In my statement I referred to it, not as eloquently or analytically, perhaps more rhetorically.

But we're talking about an issue here that touches and concerns the growth and development of the Nation.

Let me say—and I'll be very brief—the coal industry opposes legislation requiring immediate massive and costly reductions in SO_2 emissions as the means of correcting problems associated with environmental acidity.

> We are greatly worried that an acid rain cap such as contained in S. 768's acid rain provisions in effect place a cap on production, obstructing the use and expansion of our national industrial capacity.
>
> Section 183 (c) of the Clean Air Act, as it would be amended by S. 768, would provide, with the exception of coal conversions by utility boilers under the Fuel Use Act, that: "no major stationary source [within the 31-state region] which began operation before January 1, 1981, shall increase its actual rate of emissions of sulfur dioxide over that experienced by such source during calendar year 1980, unless [the source has complied with offsets requirements]."
>
> This provision and related parts of S. 768 establish the so-called "emissions cap" which is intended to prevent any increase in existing emissions.
>
> We have several major concerns with the cap features of this bill. Our main concern is the emissions cap will be a cap on productive capacity and will cause a ripple of severe consequences disrupting normal industrial operations and growth throughout the 31-state region.

The basis for coal's opposition can be summarized in six points. And I'll just hit the six points, and then I've got some stuff I'd like to put in the record.

1. There is no scientific consensus, and we heard that today repeated time after time today, on the severity or the affects of acid precipitation, much less on the effect of the so-called 50-percent reductions in SO_2 or the 80 or 90 percent, or the 8- or 10- or 12-million-ton reduction. We have seen no evidence of that to justify that here during this entire hearing, and I sat here all day to listen.

2. There is scientific evidence showing that in areas said to be most impacted by acidity, the acidity of rainfall and ground-water has been stable for the past 2 or 3 years. Indeed, there's evidence—the USGS has documented that all this so-called acidity that occurred in the 219 lakes we're talking about, of which 209 are in the

Adirondack State Park in the State of New York had been acidic long before the industrialization of the Midwest—or the Northeast, for that example.

3. There exists techniques for reducing the acidity of surface waters. And here again, all day, no one has addressed this. This is an ecologically manageable problem. The trouble is, we don't think intelligently about the issue. There is an ecological phenomenon that is well manageable. The Swedes have done it; the Scandanavians have done it at very little cost. And for the life of me, I can't understand why the environmentalists—when we suggest heal the sick lakes, the environmentalists' response is bandaid technology, bandaid. To me that speaks volumes to what their hidden agenda really is in this issue. It's not acid rain, it's to somehow manipulate the system through the fraud of acid rain, the political fraud of acid rain, to try to control growth and development in this Nation. Now, if we think of it that way, then it seems to me the manageable problem of acid rain can be treated by healing the sick lakes without curtailing economic growth and development as a nation by imposing costs on the aluminum industry, on the ratepayers of this Nation. And it's been done in Sweden. And nobody, even from the administration, is really talking about that, except that that was one or two points the President in the state of the Union address did say, we ought to accelerate the studies and heal the sick lakes.

4. Is SO_2 emissions have declined drastically as a result of the Clean Air Act, and will continue to do so. The Clean Air Act is working effectively.

5. We have heard this today, acidity is not increasing. We have heard even the scientific panels have said acidity has stabilized in those lakes. Acidity is not increasing, and SO_2 emissions are decreasing. Now, common sense—if nothing else, common sense would certainly tell you, if acidity is not increasing—which the scientists are saying—and if the SO_2 emissions, which were documented here, are decreasing, it seems that we have time to act for once in our national life rationally on this issue. And I respectfully submit that that word "rationally" is not overstated. We have the time because these are the two fundamental elements of the equation. The Clean Air Act is working.

6. And this is why I was so grateful to John Quarles of NEDA/CAAP. Point 6 in my prepared statement is that the bill reported by the Public Works and Environment Committee will shut down the economy of these United States, for the reasons that he outlined.

Last month I had the occasion to speak at a meeting of 3,000 utility engineers at the American Power Conference in Chicago. I told the audience that they, and their utility customers, and millions of other Americans are being taken in by a gigantic national fraud that is being carried on in the name of acid rain. And if it isn't presumptious, I had 11 points in the bill of indictments attempting to use perhaps a little rhetorical flourish to get some—that I had an indictment of 11 specific points—and if I can, with your approval, I'd like to put that in the record. It's a good speech, and it——

[Laughter.]

Mr. **Bagge** [continuing]. It states—"fraud" is a rather strong word, but I have searched the dictionary and I can think of no better or appropriate word than "fraud" as we try to come to grips with the political dimensions of what is known as acid rain—not the ecological phenomenon, which is manageable and which we can heal those sick lakes, I say again.

Finally, in the interest of time I'd like to leave the rest of the stuff for the record, but I do have to say that John Quarles and I see this issue in the same respect. And I treat substantially—most of my statement is addressed to the issue of the economic consequences of putting a cap—based on 1980, which was the year that we first experienced our national recession. And as John said, and I repeat in my statement here, that industries that were not operating at full capacity are limited to the level of existing output and emissions they had in the year of 1980. It doesn't make any sense. In fact, this whole bill doesn't make any sense if you accept what the scientists are saying today, that acidity is not increasing, SO_2 emissions are decreasing.

Let's heal the sick lakes. Let's do something—if the politicians and the opinion polls that are cited here that you guys have got to do something, because 3 to 1 or 4 to 1—the media has conned the public into believing this is an issue that has to be dealt with. I say deal with it. Let's pass the Byrd bill.

Thank you very much.

[The prepared statement of Mr. Bagge follows:]

STATEMENT OF

CARL E. BAGGE
PRESIDENT
NATIONAL COAL ASSOCIATON

on

IMPLEMENTATION OF THE ACID PRECIPITATION ACT OF 1980

BEFORE THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
UNITED STATES SENATE

April 30, 1984

MR. CHAIRMAN AND MEMBERS OF THE COMMITTEE, I AM CARL BAGGE, PRESIDENT OF THE NATIONAL COAL ASSOCIATON. NCA REPRESENTS COAL PRODUCERS, COAL SELLERS AND OTHER ORGANIZATIONS ASSOCIATED WITH AMERICA'S COAL INDUSTRY. I APPRECIATE THE OPPORTUNITY TO APPEAR THIS MORNING AT YOUR OVERSIGHT HEARING ON THE IMPLEMENTATION OF THE ACID PRECIPITATION ACT OF 1980.

THE COMMITTEE'S AUGUST 1982 HEARING ON THIS SUBJECT PRODUCED A VALUABLE RECORD ON THE VARIOUS CONTROL BILLS BEING CONSIDERED IN THE 97TH CONGRESS AND I AM CONFIDENT THAT TODAY'S HEARING WILL ALSO PROVIDE AN EQUALLY VALUABLE RECORD TO THE CONTINUING DEBATE IN THE SENATE ON ACID RAIN.

THE COAL INDUSTRY OPPOSES LEGISLATION REQUIRING IMMEDIATE, MASSIVE AND COSTLY REDUCTIONS IN SO_2 EMISSIONS AS THE MEANS OF CORRECTING PROBLEMS ASSOCIATED WITH ENVIRONMENTAL ACIDITY. THE BASIS FOR OUR OPPOSITION CAN BE SUMMARIZED AS FOLLOWS:

1. THERE IS NO SCIENTIFIC CONSENSUS ON THE SEVERITY OR THE EFFECTS OF ACIDIC PRECIPITATION, MUCH LESS ON THE EFFECT OF THE CALLED-FOR 50 PERCENT REDUCTIONS IN SO_2 ON THE LEVELS OF ACIDITY IN THE ENVIRONMENT.

2. THERE IS SCIENTIFIC EVIDENCE SHOWING THAT IN AREAS SAID TO BE MOST IMPACTED BY ACIDITY, THE ACIDITY OF RAINFALL AND GROUND WATER HAS BEEN STABLE FOR TWO TO THREE DECADES.

3. THERE EXIST TECHNIQUES FOR REDUCING THE ACIDITY OF SURFACE WATERS THAT, IF USED, WOULD IMPOSE FAR LESS COST ON SOCIETY AND YIELD RESULTS WITH FAR GREATER CERTAINTY THAN THE DRASTIC SO_2 CUTBACKS ADVOCATED BY THE ENVIRONMENTALISTS.

4. SO_2 EMISSIONS HAVE DECLINED DRASTICALLY AS A RESULT OF THE CLEAN AIR ACT AND WILL CONTINUE TO DO SO.

IN BRIEF, UNTIL WE HAVE A CLEAR IDEA OF WHAT THE PROBLEM IS, WE SHOULDN'T BE PRETENDING TO PRESCRIBE SPECIFIC CURES. IN THE ABSENCE OF ANY TREND OF INCREASING ACIDITY, WE SHOULD NOT RUSH TO ACTION. TO THE EXTENT DAMAGES RESULTING FROM ACIDITY ARE IDENTIFIED, THE MOST COST-BENEFICIAL COUNTERMEASURES SHOULD BE TRIED FIRST.

OTHER MEMBERS OF THE PANEL TODAY ARE BETTER QUALIFIED THAN I TO ADDRESS ALL THE TECHNICAL QUESTIONS WITH RESPECT TO ACID DEPOSITION, BUT I WOULD LIKE TO CONCENTRATE ON A FEW DIMENSIONS OF THE ISSUE.

LAST WEDNESDAY I SPOKE AT THE AMERICAN POWER CONFERENCE IN CHICAGO. I TOLD THE AUDIENCE THAT THEY, THEIR CUSTOMERS AND MILLIONS OF OTHER AMERICANS ARE BEING TAKEN IN BY A GIGANTIC FRAUD THAT IS BEING CARRIED ON IN THE NAME OF ACID RAIN.

FRAUD IS A STRONG WORD, BUT I CAN THINK OF NONE MORE APPROPRIATE. THE FRAUD IS IN THE IMAGE OF ACID RAIN BEING PAINTED BY ADVOCATES OF ACID RAIN CONTROLS.

MOST OF ALL, IT IS IN THE NATURE OF THE PROPOSALS, FOR THEIR REAL PURPOSE IS TO BULLDOZE COAL OUT OF THE ENERGY PRODUCTION PICTURE.

ACID RAIN CONTROLS WOULD IMPOSE UPON AMERICA AN ECONOMIC FREEZE IN WHICH WE WOULD BE INCREASINGLY LIMITED IN OUR ABILITY TO MEET THE CHALLENGES OF THE FUTURE. THEIR LEGACY WOULD BE A PETRIFIED ECONOMY.

PART OF THE FRAUD, MR. CHAIRMAN, IS THE FALSE PICTURE OF ACID RAIN'S CAUSES AND EFFECTS BEING GENERATED BY THE ENVIRONMENTAL GROUPS AND SOME POLITICAL FIGURES.

NO BETTER EXAMPLE CAN BE FOUND THAN THE NATIONAL WILDLIFE FEDERATION'S SELF-STYLED "COMPREHENSIVE" APPRAISAL OF THE CAUSES AND EFFECTS OF ACID RAIN RELEASED THROUGH THE MEDIA LAST WEEKEND.

THE FEDERATION ASCRIBED ACID RAIN TO SULFUR DIOXIDE EMISSIONS ALONE, ALTHOUGH VIRTUALLY EVERY SCIENTIFIC REPORT NOTES THERE ARE SEVERAL POSSIBLE PRECURSORS FOR ACIDITY IN THE ENVIRONMENT.

THE FEDERATION MAKES FREQUENT REFERENCE TO "UNPOLLUTED RAIN" HAVING A PH VALUE OF 5.6, EVEN THOUGH VIRTUALLY ALL RESPECTED RESEARCHERS ACKNOWLEDGE THAT THAT IS A THEORETICAL VALUE, NOT FOUND IN NATURE. THE PH VALUE OF "NATURAL" PRECIPITATION BEFORE ANY MANMADE INFLUENCES ARE IMPOSED FALLS IN THE RANGE OF 4.5 TO 5.6.

MR. CHAIRMAN, SOME BACKGROUND INFORMATION MAY BE USEFUL FOR THE ACID RAIN DEBATE THAT IS NOW GOING ON. IN THE 1970 CLEAN AIR ACT, AND AGAIN IN THE 1977 AMENDMENTS, CONGRESS ESTABLISHED VERY

STRINGENT STANDARDS FOR SULFUR DIOXIDE (SO_2) EMISSIONS FROM STEAM ELECTRIC POWERPLANTS. EXISTING PLANTS, WHOSE SO_2 EMISSIONS WERE LIMITED ALREADY TO A LEVEL DETERMINED TO PROTECT HEALTH AND WELFARE UNDER THE NATIONAL AMBIENT AIR QUALITY STANDARDS (NAAQS), AS WELL AS STATE LIMITS, WERE NOT MADE SUBJECT TO THESE NEW SOURCE STANDARDS. TWICE CONGRESS CHOSE NOT TO IMPOSE MORE STRINGENT STANDARDS ON EXISTING FACILITIES, ELECTING INSTEAD TO ACHIEVE AN OVERALL REDUCTION OF SO_2 THROUGH THE CONTINUOUS AND LESS DISRUPTIVE STRATEGY OF REPLACING OLDER FACILITIES WITH NEWER, MORE EFFICIENT PLANTS. SINCE NO THREAT TO HUMAN HEALTH OR WELFARE WAS OR IS INVOLVED, CONGRESS ACTED IN THE COUNTRY'S BEST INTEREST BY LETTING THE REPLACEMENT STRATEGY ACHIEVE ITS EFFECTS. THE MOST RECENT DATA FROM EPA SHOWS THAT SO_2 EMISSIONS PEAKED IN 1973 AND BY 1982 HAD DECLINED 26 PERCENT.

THE ISSUE OF ACID RAIN PER SE DID NOT ARISE DURING CONGRESSIONAL CONSIDERATION OF EITHER THE 1970 ACT OR THE 1977 AMENDMENTS TO THE CLEAN AIR ACT. IN 1980, HOWEVER, ENVIRONMENTAL GROUPS BEGAN TO PUSH FOR TIGHTER SO_2 CONTROLS ON EXISTING PLANTS, ARGUING THIS WOULD REDUCE ACID DEPOSITION. THERE IS NO EVIDENCE OF INCREASING LEVELS OF ACIDITY, AND THE LACK OF SIGNIFICANT OR RAPID CHANGES IN ACIDIC PRECIPITATION HAS BEEN CONFIRMED BY THE U.S. GEOLOGICAL SURVEY. PROPONENTS OF ACID RAIN CONTROLS FIND IT CONVENIENT TO SWEEP ASIDE THESE FACTS WITH THE ARGUMENT THAT SOME LAKES IN THE NORTHEAST ARE TOO ACIDIC TO SUPPORT FISH. ACCORDING TO THE USGS, 219 LAKES HAVE BEEN IDENTIFIED AS ACIDIC, WITH 206 OF THESE BEING IN THE ADIRONDAK STATE PARK IN NEW YORK STATE. THE FACT IS MANY OF THESE LAKES HAVE BEEN ACIDIC FOR DECADES, NOT

BECAUSE OF PRECIPITATION ACIDITY BUT BECAUSE OF GEOLOGIC AND BIOSPHERIC CONDITIONS. SOIL SCIENTISTS STATE THAT THE ACIDITY OF A PARTICULAR WATER BODY IS INFLUENCED LESS BY ACIDIC RAINFALL THAN BY THE HIGH ACIDITY NATURALLY PRESENT IN FOREST LITTER OR BY THE NATURAL BUFFERING CAPACITY (OR LACK THEREOF) IN THE SOILS SURROUNDING THESE WATER BODIES.

FURTHERMORE, THE NATIONAL ACADEMY OF SCIENCES, JUNE 1983 ACID RAIN TASK FORCE REPORT HAS BEEN WIDELY HERALDED AS A CALL FOR ACTION, WHEN IN FACT TWO OF ITS PRIMARY CONCLUSIONS ARE AS FOLLOWS:

- "FURTHER RESEARCH IS RECOMMENDED TO DEVELOP AN EFFECTIVE STRATEGY FOR DEALING WITH ACID RAIN."

- "THE COMMITTEE CANNOT PREDICT THAT SUBSTANTIAL REDUCTION IN ACID RAIN WOULD OCCUR IN SENSITIVE AREAS FROM SUBSTANTIAL REDUCTION IN EMISSIONS IN SPECIFIC GEOGRAPHIC AREAS"...IN RELEASING THE NAS REPORT, ACID RAIN PANEL CHAIRMAN DR. CALVERT STATED THAT: "WE CANNOT JUDGE WHETHER REDUCING EMISSIONS IN A SPECIFIC GEOGRAPHIC AREA WOULD HELP SIGNIFICANTLY TO ALLEVIATE THE ACID RAIN PROBLEM IN ANOTHER AREA."

THESE CONCLUSIONS WERE FURTHER REINFORCED BY THE AUGUST 1983 CRITIQUE OF THE NAS REPORT BY THE NATIONAL LABORATORY CONSORTIUM (NLC). BOTH THE NLC AND THE NAS HAVE RECENTLY RELEASED A CONSENSUS STATEMENT, CALLING ATTENTION TO THE FACT THAT THEIR FINDINGS:

> "...SHOULD PUT TO REST SOME OF THE CLAIMS BY MANY OF THE PROPONENTS OF ACID RAIN CONTROLS THAT THE NAS URGED A 50 PERCENT EMISSION REDUCTION TO ACHIEVE AN EQUAL DEPOSITION REDUCTION IN SENSITIVE AREAS. IT SHOWS THAT

> MASSIVE AND COSTLY 8, 10, AND 12 MILLION TON SO_2 REDUCTION PROGRAMS CANNOT PROVIDE ANY ASSURANCE THAT THE SO-CALLED RECEPTOR AREAS IN THE U.S. AND CANADA WILL BE PROTECTED. REQUIRING UTILITIES IN THE MIDWEST AND THE SOUTH TO CONTROL THEIR EMISSIONS BY SUCH AMOUNTS WILL NOT ENSURE PROTECTION FOR THE ADIRONDACKS, BUT IT WILL SURELY DRIVE UP ELECTRIC BILLS FOR RESIDENTIAL AND INDUSTRIAL RATE-PAYERS SERVED BY THOSE UTILITIES AND THREATEN THE JOBS OF THE NATION'S HIGH SULFUR COAL MINERS."

MR. CHAIRMAN, THE CLEAN AIR ACT IS WORKING. UNDER THE CONGRESSIONALLY PRESCRIBED NEW SOURCE PERFORMANCE STANDARDS, NEW MORE EFFICIENT COAL-FIRED PLANTS ARE REPLACING OLDER PLANTS AS THEY ARE OPERATED AT REDUCED CAPACITY OR RETIRED. CLEANER COAL AND LOWER-SULFUR COALS ARE ALSO BEING USED. AS A RESULT, SULFUR DIOXIDE EMISSIONS HAVE BEEN REDUCED DRAMATICALLY AND THIS REDUCTION WILL CONTINUE WITHOUT ANY NEW LEGISLATION. NATIONWIDE, BETWEEN 1973 AND 1982, SULFUR DIOXIDE EMISSIONS HAVE BEEN REDUCED BY 26%.

THE REDUCTION IN SULFUR DIOXIDE PRESCRIBED IN S.768 WOULD BE TANTAMOUNT TO IMPOSING A NEW FEDERAL LIMIT ON EMISSIONS FROM EXISTING COAL-FIRED PLANTS. THIS WOULD REMOVE ANY FLEXIBILITY THE STATES NOW HAVE TO MEET AMBIENT AIR QUALITY STANDARDS. IT WOULD ALSO EFFECTIVELY PLACE MANY SECTIONS OF THE NATION INTO "NON-ATTAINMENT" STATUS FOR SO_2.

FUTURE ECONOMIC GROWTH WOULD HAVE TO BE ACHIEVED IN AFFECTED AREAS BY PURCHASING COSTLY "EMISSION OFFSETS." THE DIFFICULTY IN ADDING NEW SOURCES AND THE COSTS WOULD BE COMPOUNDED BECAUSE THE CHEAPEST "OFFSETS" WOULD HAVE BEEN REMOVED. THE DEPARTMENT OF ENERGY ESTIMATES ARE THAT S.768 WOULD INCREASE ELECTRICAL

GENERATION COSTS TO THE UTILITIES BY $7.0 BILLION ANNUALLY. THIS COST MUST ULTIMATELY BE PAID BY THE CUSTOMERS. SOME UTILITIES HAVE ESTIMATED THAT THE LEGISLATION WOULD INCREASE THEIR ELECTRICITY PRICES FROM 20% TO MORE THAN 100% FOR MILLIONS OF CUSTOMERS IN THE MIDWEST AND SOUTH. THE CUMULATIVE COST OF THE LEGISLATION IS ESTIMATED AT MORE THAN $100 BILLION.

AS I POINTED OUT IN RECENT TESTIMONY BEFORE THE ENVIRONMENT AND PUBLIC WORKS COMMITTEE, THESE HIDDEN CONSEQUENCES -- AN INDIRECT FEDERALLY-MANDATED EMISSION LIMIT ON EXISTING PLANTS AND "NON-ATTAINMENT STATUS" FOR LARGE AREAS OF THE COUNTRY -- SUBVERT THE VERY INTENT OF THE CLEAN AIR ACT.

S.768, RECENTLY REPORTED BY THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS, GIVES THE IMPRESSION OF ATTACKING ACID RAIN. BUT IN REALITY, THE ACID RAIN PROVISION IS A SUBTLE WAY TO FUNDAMENTALLY ALTER THE CLEAN AIR ACT'S PURPOSE OF PROMOTING HUMAN HEALTH AND WELFARE WHILE PROMOTING ECONOMIC GROWTH.

A MORE RATIONAL APPROACH TO DEALING WITH ACID RAIN AT THIS TIME IS EMBODIED IN TWO BILLS INTRODUCED BY SENATOR ROBERT BYRD, S.454 AND S.1925. S.454 STRENGTHENS THE ONGOING ACID RAIN RESEARCH EFFORT AND PROVIDES FUNDING TO MITIGATE EFFECTED WATER BODIES. S.1925 ACCELERATES THE DEVELOPMENT AND COMMERCIALIZATION OF TECHNOLOGIES THAT WILL ALLOW COAL TO BE USED IN A MORE ENVIRONMENTALLY ACCEPTABLE MANNER. ATTACHED TO MY STATEMENT IS A LIST OF THOSE SENATORS NOW CO-SPONSORING S.454 AND S.1925.

ATTENTION IS NOW BEING DIRECTED TO FOREST DAMAGE. CURRENT KNOWLEDGE, HOWEVER, DOES NOT TELL US WHETHER THE OFFENDING POLLUTANTS ARE SULFATES, NITRATES, OXIDANTS, OR HEAVY METALS. UNTIL THERE IS ADEQUATE INFORMATION ABOUT THE CAUSES OF FOREST DAMAGE, WE MUST GUARD AGAINST THE TEMPTATION TO ACT TOO QUICKLY AND POSSIBLY CONTROL THE WRONG POLLUTANTS.

MR. CHAIRMAN, A PREMISE OF PENDING SULFUR DIOXIDE EMISSIONS CONTROL BILLS, SUCH AS S.768, IS THAT ACID RAIN IS GETTING WORSE AND, THEREFORE, WE DO NOT HAVE TIME TO WAIT FOR ADDITIONAL RESEARCH BEFORE TAKING CONTROL ACTION. THE SCIENTIFIC EVIDENCE, HOWEVER, INDICATES THAT THERE HAS BEEN NO OVERALL LONG-TERM INCREASE IN THE ACIDITY OF PRECIPITATION AND SURFACE WATERS IN THE NORTHEAST.

WE DO HAVE TIME TO WAIT. I WOULD URGE YOU AND THE OTHER MEMBERS OF THIS COMMITTEE TO MAKE YOUR VOICES HEARD IN THIS DEBATE. TO ACT AT THIS TIME WITHOUT THE FACTS COULD PROVE DEVASTATING TO THE COAL INDUSTRY. THIS CONCLUDES MY STATEMENT, MR. CHAIRMAN. I WOULD BE PLEASED TO ANSWER ANY QUESTIONS THAT YOU OR OTHER MEMBERS OF THE COMMITTEE MIGHT HAVE.

Co-Sponsors for S.454 - Acidic Deposition Mitigation and Research Act.

Introduced by Robert C. Byrd

Howell Heflin	(D-AL)
Jeremiah Denton	(R-AL)
Mack Mattingly	(R-GA)
Steven Symms	(R-ID)
John Melcher	(D-MT)
Mark Andrews	(R-ND)
Charles Percy	(R-IL)
Alan Dixon	(D-IL)
Richard Lugar	(R-IN)
Dan Quayle	(R-IN)
Walter Huddleston	(D-KY)
Wendell Ford	(D-KY)
Paul Trible, Jr.	(R-VA)
John Warner	(R-VA)
Daniel Inouye	(D-HI)
Orrin Hatch	(R-UT)

Co-Sponsor List for S.1925

Introduced by Robert C. Byrd (D-WV)

Wendell Ford	(D-KY)
Howell Heflin	(D-AL)
Bennett Johnston	(D-LA)
Jennings Randolph	(D-WV)
John Heinz	(R-PA)
Walter Huddleston	(D-KY)
Charles Percy	(R-IL)
Max Baucus	(D-MT)
Alan Dixon	(D-IL)
Jim Sasser	(D-TN)
John Warner	(R-VA)

National Wildlife Federation Report

1. Data taken from non-typical sources
    - few are current (i.e., with publication dates 1982 and pre)
    - many are obscure
    - some are drafts, when final reports are available
    - major publicly-reviewed sources not used

2. Obviously improved, generally available data not used.

3. Prior National Wildlife Federation Report (attached) includes less strident criteria for determining sensitive areas.

4. Examples of documents not cited that are in the general, and publicly-reviewed, literature:
    - o EPA's Critical Assessment Research Papers (last draft was July 1983) (the CARP)
    - o NAPAP's Annual Report - 1982; released June 1983
    - o EPA's regional sensitive aquatic area maps (so-called Omernik maps), released spring 1983

5. Examples of Presentation Problems

    SENSITIVE WATERS

    - o In NWF's prior report, they recognize (page 3)
        - surface waters with alkalinity greater than 200 u eq/l* as "low to non-sensitive"
        - waters with alkalinity between 100 and 200 u eq/l as "moderately sensitive"
        - waters less than 100 u eq/l as "highly sensitive"
    - o Present report provides a map for each state using a legend for shaded areas of:
        - (1) sensitive surface waters with alkalinities of less than 200 u eq/l
        - (2) (no descriptive name) 200 to 399 u eq/l
        - (3) higher micro equivalent values indicate an increased buffering capacity

* micro equivalent per liter

The text (pg. iii) claims that EPA researchers at Corvallis consider waters of less than 200 u eq/l to be "highly sensitive to acidification."

- o The CARP (page 4-19) states "The logic behind alkalinities of less than 200 u eq/l as an upper long-term sensitivity limit is as follows: ...".
- o DOE provided comments (Williams, August 1983) stating even this characterization of a threshold as being too high. These comments have not been refuted by the researcher and I would anticipate that the final product would be modified to reflect these comments (at least, partially).
- o Therefore, quite different maps and interpretations could have been made from available maps and reports of EPA that have undergone public comment.

EMISSIONS LEVELS

- o NWF statement is that SO2 emissions have tripled since 1950 and are projected to increase another 2 to 3 million tons annually by the year 2000.
- o The EPA report that is often cited by Ruckelshaus states that SO2 emissions rose from 20.4 million tons in 1950 to 28.9 million tons in 1973, and have declined since to 21.4 million tons in 1983 -- obviously they did not triple.
- o If the projection conjecture were believed, SO2 emissions in 2000 would be 20 + (30 to 45) million tons (i.e., 50-65 million tons); no Federal study has projected growth of these proportions (and some scenarios show declines).

NATURAL RAIN

- o Statements throughout the NWF report compare pH to their claimed natural pH of 5.6.
- o Many reports over the past 3 years point out that water balanced with a normal atmosphere is in the range of 5.2 to 5.0. The draft NAPAP report (not out) will state new measured data is 5.0 as a benchmark. Bernabo testimony will cite 5.0.

AGRICULTURAL EFFECTS

- NWF mentions that crop yield reductions have been documented for two crops. It doesn't mention that there is extensive literature that lab experiments have stimulated growth for a few species and not affected most species. It also does not point out the general finding of many assessments that other soil management practice outweigh acid deposition impacts on managed soils.

REPORTED REGIONAL EFFECTS

- NWF Report deals with 21 states, none being New England. While they report depressed pH in rain for all 21, this is based on the 5.6 criterion.
- Of the 21 states, actual effects on organisms or chemistry is:

  No Reported Effect - 8 states
  Possible Effect - 2
  Chemical Effect - 4
  Biological Effect - 7

- The seven states are: New York, New Jersey, Pennsylvania, West Virginia, Wisconsin, North Carolina, and Florida. Sources are typically 1982 or earlier. Majority of cited results were included in the U.S./Canada MOI report and covered in detail, often heavily caveated, in the CARP.

NATIONAL COAL ASSOCIATION

THE ACID RAIN FRAUD
A CRIMINAL INDICTMENT
AND
A DEMAND FOR A NEW TRIAL

LUNCHEON ADDRESS
BY
CARL E. BAGGE
PRESIDENT
NATIONAL COAL ASSOCIATION

AT THE
1984 AMERICAN POWER CONFERENCE

SPONSORED BY THE
ILLINOIS INSTITUTE OF TECHNOLOGY

CHICAGO
APRIL 25, 1984

THE ACID RAIN FRAUD:

A CRIMINAL INDICTMENT AND A DEMAND FOR A NEW TRIAL

I am grateful to the officers of the American Power Conference who have invited me, once again, to visit with you. For this important national utility forum is a homecoming for me in more ways than one.

I recall your first invitation 15 years ago when, as a regulator of your industry, as a member of the Federal Power Commission, I warned you of the imminent coming of the environmental movement.

I addressed you then as Chairman of the President's inter-Agency Task Force on Utilities, which was attempting to make your facilities look good. At that time, the emerging environmental movement was benign in nature and expressed itself with a concern for aesthetics. The response of the utility industry was to coin a new phrase—"beautility"—and to bury distribution lines and improve the appearance of your transmission lines.

Who would have imagined 15 years ago that this benign effort to make the utilities sensitive to aesthetics would be politicized and transformed into the parapolitical movement which it has become today?

But your industry's leadership capitulated to these emerging parapolitical forces through the years in order to secure media and public acceptance on issue after issue, until today there is nothing more left for you to concede about nuclear generation, for example.

I pray God that what your industry has permitted to be conceded away in the nuclear area will not now be visited upon your coal fired generation. For today coal is the new battleground. Those forces, flush with triumph in the nuclear arena, now seek to also eliminate coal.

Hear the words of the Sierra Club in a political directive issued to its political street fighters early this year: "In the long term, the use of coal will prevent other fuel development, thus threatening the survival of man."

They clearly seek to destroy central power generation, by whatever form, in their irrational zeal to create a society which only these visionaries embrace--a society which is not based upon our historic national goal of broadening our nation's economic pie through growth and development.

Having warned you of its emergence from this platform 15 years ago, let me warn you today of its militant transformation and its political goals which strike at the very heart of your industry and mine.

In doing so, let me share with you coal's burden—the acid rain fraud—and ask you to join the coal industry in pressing our government for an indictment of its perpetrators and demanding a new trial of this issue at the bar of public opinion.

All of us who are concerned with the nation's electric utility industry are familiar with the issue of acid rain, both as a scientific and ecological phenomenon and in its separate and wholly unrelated political incarnation as well.

In its political incarnation it has been covered by television and given feature treatment by every kind of publication. Commentaries about it have been prominent in the opinion pages of a great many newspapers. Indeed, the nation has been immersed in and saturated with political acid rain.

You know what's being said. Comments like these:

From the Baltimore Sun, for example: "The story of acid rain is the story of dying and dead lakes, landscapes turned into moon-like vistas, and the complete ecological decimation of whole plant and animal systems in certain parts of the world."

Quite a picture, isn't it?

Or this, from the New York News: "In our book, the evidence is clear that lakes and forests in wide areas of the Northeast and Canada are being poisoned by rain and snow laced with sulfur dioxide produced by polluters, mostly in the Ohio River Valley."

And from the St. Louis Post-Dispatch: "Acid rain...kills life in lakes and streams and has damaged forests, particularly in the Northeastern U.S. and eastern Canada."

The scientists don't have all the evidence but apparently the editorial writers do!

And finally, this gem from the St. Petersburg Times: "If trees are choking on pollution, what is happening to the people who breathe the same air?"

The images conjured up in the public's mind by these kinds of editorial opinion and by political cartoonists' pens are far more vivid than the heavy prose of scientific reports. But unfortunately, these images are far more likely to stimulate political interest and action than the deliberate, dispassionate statements of the scientific community.

My fellow Washingtonian Daniel Boorstin, the Librarian of Congress and an eminent historian, once wrote that "We are haunted, not by reality, but by those images we have put in place of reality." As a historian, Boorstin was speaking of how we interpret our past. But he just as well might have been talking about the present. For there as well, images all too easily can and do take the place of reality.

Today there is no better example of how the image is obstructing reality than acid rain. The image goes far beyond the manageable ecological problem of acidity. Indeed the image of acid rain, as a political phenomenon, has a life of its own, wholly unrelated to the reality of the ecological phenomenon.

All across our land, the coal and electric power industries have been summoned to the court of public opinion, tried on a flimsy foundation of hearsay and half-truths, convicted in the images of cleverly concocted acid rain cartoons, and eloquently executed by editorial writers.

Were reason to prevail, a mistrial would surely be declared. But as someone once said, it's difficult to reason a man out of what he hasn't reasoned himself into. Nevertheless, I insist on a new trial. I demand a new trial. The American public, who are the unwitting victims of this monumental fraud, are entitled to a new trial.

Today at this historic American Power Conference, I charge the parapolitical groups posing as environmentalists, as they do in this country, and the Canadian government with the common law crime of "fraud in the inducement." For they have fraudulently and willfully and with malice aforethought induced the American public to cut its own throat, to fall on its own sword, to halt economic growth in order to satisfy the hidden social agenda of the "greens" and the political and economic agenda of the Canadian Government.

Let me share with you the specific charges which constitute my bill of indictment:

Count one: The public is being defrauded into believing that acidity is increasing. That's the argument used by Congress to justify immediate, drastic, cost-be-damned emissions control legislation.

The longest running studies and most extensive monitoring of acidity in the environment have been done in the Northeast. The U.S. Geological Survey, whose credentials for credibility are impeccable, recently summarized over 200 individual research reports covering a 30-year span.

The USGS concluded that acidification of surface waters in the Northeast is not worsening. Most of the problem occurred before the mid- to late-1960s. Since then the situation has been largely stable and, in some cases, has shown a slight recovery. The USGS also found that the acidity of precipitation has been stable since the mid-fifties.

Count two: The public is being defrauded into believing that acidity is a widespread problem.

Now there is a basic fact upon which most parties in the debate seem to agree--some lakes in the Northeastern United States and Canada are too acidic to support fish populations.

In the United States 219 lakes have been identified as acidic. And 206 of these lakes are in the Adirondacks. These 206 lakes account for only 4 percent of the lake surface in New York State. It is also a fact that many of those lakes were acidic long before urbanization of the Midwest.

So, far from being a widespread problem affecting many parts of the United States, it is a highly localized problem. The same applies in Canada.

Count three. The public has been defrauded into believing that our forests are being destroyed by acid rain.

The best that scientists can say today is that they don't know what is causing the changes in growth of some tree species.

Science News Magazine, in its April 7 issue, quotes Arthur Johnson of the University of Pennsylvania, one of several researchers looking into the problem, saying this: "A lot of work needs to be done to understand whether it's a natural phenomenon of whether it's due to air pollution or a combination of circumstances."

It also quotes the author of a report by Worldwatch, an environmental think-tank, as saying that "No single hypothesis can explain everything that's happening everywhere."

So those who raise the specter of dead forests and attribute their decline to sulfur dioxide emissions from coal-fired power plants in the Midwest and acid rain are defrauding the public.

Even the forest products industry, which has a larger stake than anyone in the health of the nation's forests, can document no acid-rain damage to the trees it depends on for wood supply.

EPA Administrator William Ruckelshaus recently told a congressional subcommittee that while the information about forest effects is troubling, the uncertainty about their causes "raises the possibility that if we act too quickly, we may control the wrong pollutant."

Count four. The public has been defrauded into believing that acid rain threatens peoples' health.

There is absolutely no evidence that acid deposition has a direct effect on human health. And according to the Environmental Protection Agency, indirect health effects have not been demonstrated in human populations. The EPA notes, for example, that "the pH of acidic deposition is generally well within the range normally tolerated by human skin and eyes."

A report prepared by the U.S. Comptroller General says claims that some individuals are affected fatally by acid precipitation—a preposterous allegation on its face—are not substantiated by scientific research.

"Such statements attract public attention but either do not reflect the current state of knowledge or exaggerate available evidence," it says.

In other words--much to the dismay of the headline writers--killer rains simply do not exist.

Count five. **The public is being defrauded into believing that SO_2 emissons are rising.**

Its latest report, issued in February, the Environmental Protection Agency shows that since 1970 SO_2 emissions have declined 25 percent. There just is no way to avoid recognizing this fact. Sulfur dioxide emissions are declining, not rising.

Emissions from coal-fired facilities alone have gone down more than 14 percent during that time, even though the use of coal has risen 85 percent because it is our most abundant, low-cost fossil energy resource.

Count six. **The public is being defrauded into believing that coal-fired plants in the Midwest are the cause of acidity in the Northeast.**

The idea that acid rain in the Adirondacks and Northeast is a result of long distance transportation of SO_2 emissions from coal-fired power plants 600 or more miles away in the Midwest is no more than a hypothesis. It ought to be recognized as such and not a reported as a fact.

Even the National Academy of Sciences has been unable to determine precisely how and to what extent pollutants from one region affect others. If anything, data show that local sources may be more the culprit.

Here is what the National Academy has to say: "It can be stated as a rule of thumb that the farther a source is from a receptor site, the smaller the influence..."

Count seven. **The advocates of more stringent controls on SO_2 emissions are fraudulently leading the public to believe that coal-fired facilities are the only source of acid forming emissions.**

Without question, coal-fired power plants are not the sole emitters of suspected acid precursors. The scientific literature supports me on that.

Sulfur dioxide and nitrogen oxides, for example, are created by nature and biological processes, by motor vehicles which run on gasoline and diesel fuel, and by oil-fired boilers--which along with motor vehicles are the predominant source of pollutants in the "sensitive areas" of the Northeast which claim acid rain damages.

To lay the blame at coal's feet is to ignore these facts, and to ignore the very complex chemistry of atmospheric acidity that requires taking into account more than just SO_2 emissions from coal.

Count eight. The American public is being fraudently deceived into believing that the United States has done nothing to control acid rain.

People are being told our government is sitting on its hands. The reality is that the United States is a world leader in the control of environmental pollution, under the Clean Air Act—which has been the law of the land for 14 years.

I could do no better than to repeat what Secretary of State Shultz told the Canadian government in a diplomatic note delivered last month:

> The Clean Air Act has resulted in a 25 percent decrease in sulphur dioxide loadings since 1973, and a 43 percent decline from the projected 1980 level that would have resulted from the increase in utility growth in the absence of controls.
>
> "U.S automobile emission standards have reduced emissions for new vehicles by 90 percent for hydrocarbon and 75 percent for oxides of nitrogen. New coal-fired power plants in the United States are equipped with state-of-the-art flue gas cleaning systems.
>
> "These efforts have not been cheap. Over $48 billion has been invested. Additional expenditures, including fuel switching and operating expenses, have pushed the total cost to approximately $150 billion."

Count nine. The public is fraudulently induced to believe that the Canadian government and governments in the Western Europe are doing more than the United States to control suspected precursors of acid rain.

To establish a context, let me quote from a recent editorial in the Baltimore Sun because its message is one being repeated in editorials all across the country. The Sun wrote, "...there is one significant difference between the two countries: The Canadians are clearly committed to cleaning up acid rain pollutants....Here in the United States we continue only to study the problem."

In case you don't know it, the finger-pointers north of the border do not require pollution control devices on their motor vehicles. There are no catalytic converters on cars in Canada.

The Canadians do not have a single scrubber in service to remove pollutants from Canadian emissions. Here in the United States there are 111 scrubbers operating at electric utilities, and 51 more are planned.

And by the Canadian Government's own admission the dead lakes up there are in the shadow of the Sudbury smelter, the largest SO_2-emitting facility in North America.

Editorials that would indict American environmental efforts do not tell readers that the United States has already reduced its SO_2 emissions 25 percent under the Clean Air Act and that reductions are continuing.

Those editorials do not say that SO_2 emissions in Canada are twice those of the United States, on a per capita basis.

Those editorials do not report that reductions in SO_2 emissions in Canada have been due to declining production by the copper-nickel smelting industry and to increasing use of nuclear and hydro generation and not to governmental policies or laws intended to improve the environment.

There's another aspect of the Canadians' interest in promoting acid rain controls in the United States that seldom gets attention.

During the past few years this country has made a valiant effort to become less dependent on foreign sources of energy. Of course, we always think about OPEC oil when we talk imported energy. No one really thinks about energy imported from Canada.

Energy Secretary Hodel, in recent testimony on acid rain before Congress, expressed his concern regarding growing electricity exports to the United States. He noted that in 1982 the United States imported from Canada 34,000 gigawatt-hours of electric power—the equivalent of twelve 500 megawatt coal-fired power plants operating at 65 percent plant factor. The Canadian Energy Research Institute estimates that beyond 1990 the total potential market for Canadian power in the U.S. could be 15 to 30 times today's level.

Obviously, if the United States produces less power because of repressive constraints on generation, one beneficiary would be the power producers in Canada who are building more nuclear and hydro plants. Adding insult to injury, the Canadians are seeking U.S. financing for one of their nuclear plants which will export nuclear power to the United States.

Recently, the press highlighted reports that Canada and nine European countries have signed an agreement to reduce sulfur dioxide emissions 30 percent in the next 10 years. The so-called "30 percent club," they are being dubbed by the press.

These countries and the press would have you believe that we —the United States—are remiss in not being a member of the club. The fact is that they have just agreed to do in the future what we have already accomplished.

Isn't it ironic that a handful of countries that either have no environmental protection laws or have just adopted some sort of statutes are being held out as the leaders, while the United States, which has the strongest environmental protection laws in the world—and has had stringent Clean Air legislation for 14 years—is held up to international ridicule by its own ill-informed media?

Count ten. The public is also being defrauded into believing that the SO_2 control bills being promoted as acid rain panaceas will impose virtually no cost on Americans.

Two parties are prominent in claiming that SO_2 emissons can be reduced at little or no cost. These parties are the Canadian Government and our own TVA. What they are not telling anyone is that their emissions will be reduced in the normal course of events—in the case of Canada, because of increased reliance on new hydro and new nuclear power facilities, and in the case of TVA because of the completion of several large nuclear units.

Such costless reductions are not available to all U.S. utilities and to suggest that they are is nothing less than fraud.

The Department of Energy two years ago issued a study that considered cost estimates developed by several independent groups. To summarize it, SO_2 reductions of the magnitude being proposed on Capitol Hill will cost consumers $100 billion over 30 years. When the effects of inflation are taken into account over 30 years, the real dollars could be as much as $300 billion.

Count eleven: The ultimate fraud lies in the very nature of the proposal itself. While the legislation fradulently purports to attack acid rain, in reality it is a subtle way to alter fundamentally the Clean Air Act's purpose in promoting human health and welfare while continuing economic growth and development.

Acid rain is only a facade for the forces who would deliberately destroy the carefully-crafted balance of environmental and economic goals that have been achieved by the Clean Air Act during the last decade.

The mandated reduction of SO_2 emissions being proposed would effectively place large sections of the nation in "non-attainment" status for SO_2. All future economic growth would have to be achieved by purchasing costly "emission offsets."

The difficulty and cost of adding new sources would be compounded, because the cheapest "offsets" would have been removed in first mandated reduction by which compliance was achieved in the first place.

The combine of interests, who advocate massive reductions in sulfur dioxide emissons to cure the effects of acidity, pose a much greater threat to the future of our society than do the manageable ecological effects of acid deposition. They are the real problem.

By limiting energy and halting economic growth, they have the potential to alter—fundamentally and permanently—the very foundation of our prosperity. And by doing so they would foreclose economic opportunities to todays disadvantaged and to tomorrow's future generations. This, then, is the ultimate fraud!

Let me be perfectly clear about what I am calling a fraud. It is not the acidity of lakes in the Adirondacks or lakes in the shadow of the Sudbury stack in Canada.

What I am calling a fraud is the political phenomenon that goes by the name of acid rain. We all should be concerned about the acidity of lakes, in the Adirondacks and in Canada, but there's a proper response to this manageable ecological problem.

First, common sense if nothing else dictates that we move as quickly as possible to mitigate the effects of acidity in these lakes.

Where lakes and streams are acidic, we should take immediate action to restore the waters to productive status. That course of action is being followed elsewhere with good results and at far less cost than massive reductions of SO_2 that will have little or no effect on the acidity of these waters.

The fact that environmentlists reject as a "band-aid" solution a positive program of healing sick lakes now speaks for itself as to their real agenda.

Second, accelerate the existing national commitment to research into the causes and effects of acid deposition.

President Reagan advocated this policy in his State of the Union message in January. Senator Robert Byrd and Congressman Nick Rahall have proposed legislation to effect such a course of action.

Theirs is the responsible course.

For if the acidity of waters in the Northeast is not increasing and emissions are declining and will continue to decline as a result of the of the Clean Air Act, the nation need not make that hundred billion dollar crapshoot. The answers to our questions should come from the research.

A few weeks ago we all observed the various Democratic candidates in New Hampshire, stumbling all over themselves to upstage each other in enunciating emission control policies for acid rain.

How pathetic it was, seeing these supposed leaders of our country pandering to the environmentalists and to the public opinion polls.

I ask you, how can anyone compare them with our President, who has refused to be a party to the fraud. I ask you, on the basis of this sharp contrast, who do you believe should have access to the levers of political power in this nation?

The central issue for us today is this: What kind of a society are we forging for the future?

I submit that the parapolitical forces opposed to economic growth, those who find acceptance masquerading as environmentalists, have a vision of our future that is not shared by most Americans.

It is up to us to stop them from defrauding the American public, whom they manipulate and do not trust.

Even as regulated public utilities, you have the legal right—indeed, the moral responsibility—to draw the line, to stand up and be counted in your own interest, in the interest of your consumers and ratepayers, and in the interest of your country. For each of their sakes, don't make any more irrational concessions.

Indeed, I ask even more of you. I ask you, as engineers, as professionals, as practical men and women who deal with reality and not imagery, to join the coal industry in our fight against the fraud of acid rain controls.

The engineering professionals of this great utility industry can make a difference, if your voices are heard, both collectively through your engineering societies and individually.

For this we all must take a stand: for reason...for science...for reality over imagery, in order to preserve our historic national values of economic growth. For in the final analysis, that is precisely what acid rain is really all about. I pray God you hear my call and act on it.

Senator **Warner**. Well, I have spent a great deal of time, as have you and all of us, on this issue. I must say, I find that there are very well informed and conscientious individuals, struggling to resolve this dilemma on both sides, and it's a heavy weight of burden on the Congress.

I, and others, should approach this resolution with great caution. We have got to somehow solve the problem.

And I want to express my appreciation to all who waited patiently and for taking your time today to come from distant places to make very valuable contributions to our responsibility to properly legislate on this issue.

Thank you very much.

[Whereupon, at 4:30 p.m., the hearing was adjourned.]

APPENDIXES

APPENDIX A

Materials Submitted for the Record at the Request of Senator Robert Byrd

1. "Acid Rain Legislation and the Future of the Eastern Low-sulfur Coal Industry", by Larry B. Parker and Duane A. Thompson. Prepared at the request of The Honorable Robert C. Byrd by the Congressional Research Service, Library of Congress. April 6, 1984.

2. Temporal Trends in the Acidity of Precipitation and Surface Waters of New York, by Norman E. Peters, Roy A. Schroeder, and David E. Troutman. (United States Geological Survey Water-Supply Paper 2188). 1982.

3. An Evaluation of Trends in the Acidity of Precipitation and the Related Acidification of Surface Water in North America, by John T. Turk. (United States Geological Survey Water-Supply Paper 2249). 1983.

4. "Acidity Status of Lakes in the Adirondack Region of New York in Relation to Fish Resources," By Martin H. Pfeiffer and Patrick J. Festa. (Bureau of Fisheries, Division of Fish and Wildlife, New York State Department of Environmental Conservation) August 1980.

5. "An Open Letter to Governor Mario Cuomo Regarding Acid Rain Legislation", from William M. Brown, Ph.D., Director, Energy and Technology Studies Division, Hudson Institute, Croton On Hudson, New York. December 20, 1983.

6. "National Air Pollutant Emission Estimates, 1940-1982", by the Environmental Protection Agency. (EPA Document no. 450/4-83-024) February 1984. (See answers to questions from the Department of Energy in appendix D.) The full document is retained in the Committee files.

7. Acid Rain Legislative Proposals, As of the end of March 1984. Two papers: I. "The U.S. Politics of Acid Rain", and II. "The Economic and Energy Policy Implications of Pending Acid Rain Legislative Proposals", by George Clemon Freeman, Jr. The document is retained in the Committee files.

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ACID RAIN LEGISLATION AND THE FUTURE OF THE EASTERN LOW-SULFUR COAL INDUSTRY

Prepared at the request of
The Honorable Robert C. Byrd
United States Senate

by

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April 6, 1984

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ACID RAIN LEGISLATION AND THE FUTURE OF THE EASTERN LOW-SULFUR COAL INDUSTRY

SUMMARY AND CONCLUSIONS

This paper examines the potential impact on the eastern low-sulfur coal industry of various bills mandating reductions in sulfur dioxide (SO2) emissions by existing stationary sources. "Low-sulfur" is defined as coal which, when burned, emits 1.2 pounds of SO2 per million Btus or less (also called compliance coal). In particular, the paper analyzes potential production and price impacts of the dozen major SO2 reduction bills on the low-sulfur coal industry and the implications of such impacts on electricity consumers. Also, there is a brief review of current low-sulfur coal resources and reserves and a description of the industry.

The analysis suggests that the increase in eastern low-sulfur coal demand from a "least-cost" (i.e., assuming an essentially unhindered competitive market) 10 million ton SO2 reduction strategy would be in the lower half of the 35 to 50 million ton range projected by the various studies to occur by 1990. Indeed, under certain circumstances, the increase could fall below that range altogether. The upper part of the projected range results primarily from an assumption that Midwestern utilities are unwilling or unable to switch to lower-rank, subbituminous western coals in response to acid rain legislation. However, historical evidence with respect to Midwest utilities meeting State Implementation Plans (SIPs) suggests that western subbitiminous coal is a viable alternative in parts of the Midwest. This alternative will reduce the increases in production, price, and jobs experienced by eastern coal producers.

The reaction of low-sulfur coal producers in the export market (and possibly, medium volatile producers in the metallurgical market) to potentially higher prices may further reduce the projected increase. Given current conditions in the export market, even a small increase in low-sulfur coal prices resulting from acid rain legislation would provide producers with a strong incentive to switch production to the domestic steam market. The extent to which this could occur would depend on how many producers have compliance quality coal and how much of the coal was suitable for use in a utility boiler. Theoretically, if sufficient suitable coal, currently or projected to be dedicated to the export market, is shifted to the domestic steam market, the net 1993 production in central Appalachia could be no greater than that projected under a no acid rain program scenario.

Assuming some modest incremental increase in low-sulfur coal production occurs from acid rain legislation, it probably would not significantly accelerate depletion of eastern low-sulfur coal reserves. Also, if the price of low-sulfur coal at the mine rises, then the demonstrated reserve base would also increase. However, such production increases may strain the coal supply infrastructure, but the extent of the potential problem is unclear.

With some western coal penetration and shifting from export to domestic steam markets expected, this analysis concludes that minemouth price increases for eastern low-sulfur coal would also tend to be in the middle to lower half of the zero to $13 a ton (1983 dollars) range projected under a 10 million ton SO2 reduction program. (The zero increase is the result of OTA's use of historical data to project future markets.)

Fuel-switching to low-sulfur coal is generally assumed to be the least-cost SO2 control option. However, the lower mine-mouth price increases suggested by this report do not necessarily mean that fuel-switching would increase even more than that projected by studies assuming higher prices. The choice of fuel-switching versus alternatives is determined on the basis of delivered coal prices and other site-specific factors, not mine-mouth costs. These other variables include high-sulfur coal prices, technological S02 control costs, and perhaps most important, projected transportation costs. The amount of fuel-switching which would occur under acid rain legislation would be determined primarily by the amount of economic rent (i.e. the producer surplus which arises because supply is not perfectly elastic) created by the increased demand for compliance coal, and how much of that rent is captured by utilities (and therefore consumers) as opposed to other participants in the coal supply chain.

Advocates of the "least-cost" method of paying acid rain reduction costs assume that most of the rents created under acid rain legislation will accrue to electricity consumers. This would save them (and society in general) money which would otherwise be spent on more inefficient alternatives. However, consumers are the last link in the coal supply chain from extraction to preparation to transportation to conversion and, therefore, may be allocated only enough rent to prevent the utility from choosing an alternative control strategy. This suggests the possibility that cost differentials projected by some macro-economic models between "least-cost" strategies and partially or fully technology-mandated strategies that attempt to protect part of the high-sulfur coal industry's production may be significantly overstated from the view of electricity consumers. This may have significant implications for the acid rain debate. Consumer savings is the primary reason given for accepting the significant economic dislocation in high-sulfur coal regions resulting from a least-cost approach, rather than to attempt to protect at least some high-sulfur coal industry jobs by encouraging a more technologically-based approach. If the savings do not accrue to electricity consumers, then those consumers may be only marginally better off than under a more technologically-based approach, while the adverse impacts of the least-cost strategy on the high-sulfur coal industry would remain just as severe.

INTRODUCTION

In an effort to mitigate acid rain damage, several bills have been introduced in the 98th Congress to reduce sulfur dioxide (SO2) and nitrogen oxides (NOx) emissions from utility and industrial plants. A primary focus of the discussion on these bills have been the cost of compliance in terms of higher utility bills. Utilities have generally argued that political constraints will force them to place flue gas desulfurization (FGD) units on their plants, increasing electricity rates. The coal companies and United Mine Workers Union have argued that utilities will generally switch from burning high-sulfur coal to lower sulfur coal because switching is generally considered less expensive than installing FGD units. Finally, various econometric studies conducted for Government agencies and interest groups have suggested that a "least-cost" mixture of FGD units and fuel-switching may occur, which would minimize electricity rate increases. 1/ This final scenario assumes economically rational behavior by utilities and, therefore, tends to favor fuel-switching heavily over FGD units because of costs, but includes some FGD units because of various technical, contractual, and site-specific constraints to fuel-switching.

1/ Parker, Larry B. Summary and Analysis of Technical Hearings on Costs of Acid Rain Bills. CRS unnumbered report prepared for the Senate Committee on Environment and Public Works, July 26, 1982.

In addition to affecting electricity prices, an acid rain bill could have a strong impact on the coal industry in major coal-producing States. If a State attempts to minimize electricity rate increases from acid rain legislation, it will tend to maximize the impact on high-sulfur coal-producing States by favoring fuel-switching over FGD units. If a State attempts to protect its local high-sulfur coal industry by insisting on FGD units, it will tend to maximize the electricity rate impact of the legislation, at least in the short term.

As indicated by a previous CRS report 2/, the resulting local employment impact on the high-sulfur coal industry from a "least cost" implementation strategy could be severe in some regions, particularly in the Illinois Basin and Ohio. Reemployment in the newly-created low-sulfur coal industry is very uncertain given the considerable distance between the affected high- and low-sulfur coal regions and the high likelihood that other workers would receive the jobs created by expansion in the low-sulfur coal regions. Indeed, many questions have been asked about the assumptions of the least-cost approach: (1) Is the eastern low-sulfur coal industry capable of expanding and maintaining production capacity at the levels projected by the various studies? (2) Are the coal markets competitive? (3) How high would low-sulfur coal prices go under acid rain legislation? and, (4) How would utilities really respond to acid rain legislation?

2/ Parker, Larry B. Mitigating Acid Rain: Implications for High-Sulfur Coal Regions. Unnumbered CRS Report, May 16, 1983.

In response to these uncertainties and potential job losses in the high-sulfur coal industry, a wave of bills has been introduced to at least partially protect high-sulfur coal industry jobs by encouraging use of technology to meet any reduction requirement. Generally, such bills include a subsidy to utilities for installing technology to reduce SO2. Such a subsidy has upset some who believe the technology approach is inefficent and will cost electricity consumers more. Indeed, some have suggested that it would be cheaper for the government to provide pensions for the high-sulfur coal industry workers whose jobs would be lost through acid rain legislation than to subsidize technological alternatives.

Whether a least-cost approach to SO2 emission reductions would be significantly less expensive for electricity consumers than a technological approach depends primarily on how the low-sulfur coal supply chain would respond to acid rain legislation. This paper attempts to analyze this question by examining the current and projected situation in the eastern low-sulfur coal regions of the country in the face of proposed acid rain legislation. The discussion is divided into four parts: (1) current dynamics in the low-sulfur steam coal market, (2) factors influencing price of low-sulfur coal, (3) future low-sulfur coal demand, and (4) potential impact of least-cost strategies on low-sulfur coal. In addition, two appendices provide background on resources and reserves,* and a general description of the low-sulfur coal industry. The paper does not discuss the underlying controversy surrounding the merits of any proposed SO2 reduction program.

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* Arrangements for use of Keystone materials in this appendix were made by phone with Mr. Charles Richardson, General Manager, Keystone Coal Industry Manual. McGraw-Hill Publishing Company, 1221 Avenue of the Americas, New York, N.Y. 10020.

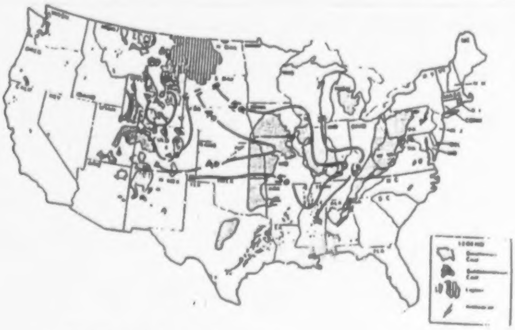
CURRENT DYNAMICS IN THE LOW-SULFUR COAL MARKET

As discussed in Appendix A, the central Appalachian region (particularly southern West Virginia and eastern Kentucky) is the primary source of eastern low-sulfur coal. Historically, this low-sulfur coal production has gone primarily for metallurgical purposes, as discussed in Appendix B. Generally, high-volatile, low-medium sulfur (1 to 1.5 percent sulfur) coal (primarily in Eastern Kentucky) was used in the area and some out-of-state markets such as Michigan and North Carolina for steam purposes. However, passage of the Clean Air Act in 1970 led to increased demand for low-sulfur coal for steam purposes. As a result, eastern low-sulfur steam coal producers and western low-sulfur coal producers began competing as each attempted to expand its markets into the Midwest and South. How this competition would play out under acid rain legislation is a key variable to increased production in central Appalachia.

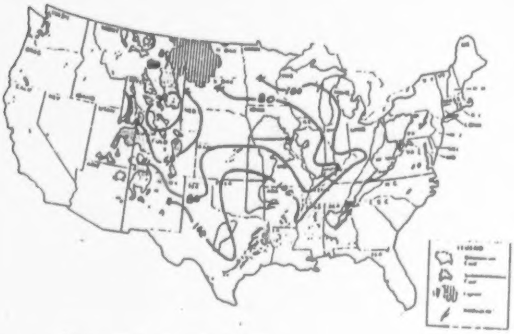
Western low-sulfur coal has penetrated into the Midwestern coal market both for the firing of new powerplants and conversion of older plants to meet State Implementation Plans. Over the past ten years, this penetration has been very impressive. Figure 1 shows iso-cost curves for Wyoming coal for 1973, 1976 and 1980. As suggested, Wyoming coal sales have progressed steadly eastward over the seven year period. This coal has made significant gains in the Great Lakes region in States, particularly Wisconsin and Michigan. Gains have also been made in the South through Oklahoma, Texas, Lousiana, and Mississippi.

Low-sulfur eastern coal has shown a somewhat different path. Figure 2 illustrates that eastern low-sulfur coal has moved primarily north into New York and south into South Carolina, Georgia, Mississippi, and Alabama. Some advances have also been made in Ohio and eastern Indiana.

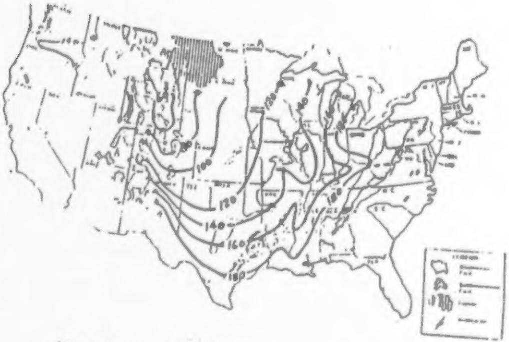
Figure 1: Iso-cost Curves for Wyoming Coal: 1973, 1976, 1980



Iso-cost curves for Wyoming coal 1973.
Delivered prices in nominal cents per million Btu.



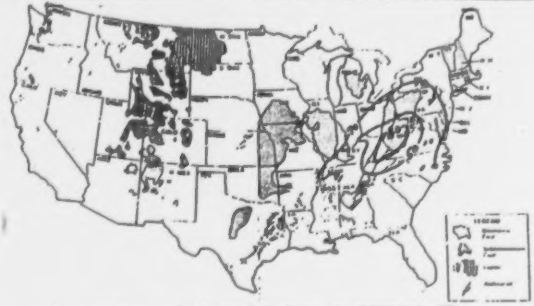
Iso-cost curves for Wyoming coal 1976.
Delivered prices in nominal cents per million Btu.



Iso-cost curves for Wyoming coal 1980.
Delivered prices in nominal cents per million Btu.

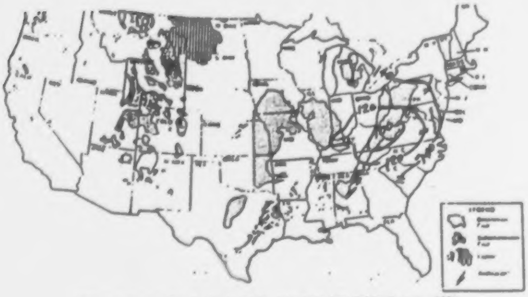
Source: Dervied from FPC form 423 by E. H. Pechan and Associates

Figure 2: Iso-cost Curves for E. Kentucky/West Virginia Low-Sulfur Coal: 1973, 1976, 1980



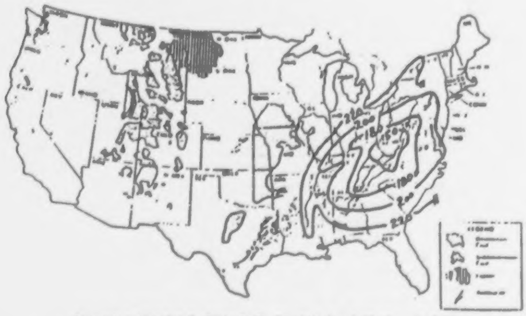
Iso-cost curves for E. Kentucky/W. Virginia Low Sulfur coal, 1973.
Delivered prices in nominal cents per million Btu.

*NOTE: Low Sulfur specified as less than 1.2 pounds SO$_2$ per million Btu.



Iso-cost curves for E. Kentucky/W. Virginia Low Sulfur* coal, 1976.
Delivered prices in nominal cents per million Btu.

*NOTE: Low Sulfur specified as less than 1.2 pounds SO$_2$ per million Btu.



Iso-cost curves for E. Kentucky/W. Virginia Low Sulfur* coal, 1980.
Delivered prices in nominal cents per million Btu.

*NOTE: Low Sulfur specified as less than 1.2 pounds SO$_2$ per million Btu.

Source: Dervied from FPC form 423 by E.H. Pechan and Associates

Because Wyoming coal is subbituminous, a 20 to 30 percent price advantage is generally considered necessary to consider it over a high-grade bituminous coal such as found in central Appalachia. Assuming this to be correct, the current line of demarcation between eastern and western coal markets appears to run from Lake Erie across the southern boundary of Michigan, down the western part of Indiana to the Ohio River, down the Ohio River to the Mississippi, and then down the western part of Mississippi to the Gulf. Obviously, this line is not rigid as site-specific considerations result in outliers (western coal in Ohio, eastern coal in Illinois).

An examination of market shares indicates the same general pattern as the iso-cost curves. Figures 3 and 4 shows coal consumption patterns for electric utilities in 1966 (before enactment of the Clean Air Act)

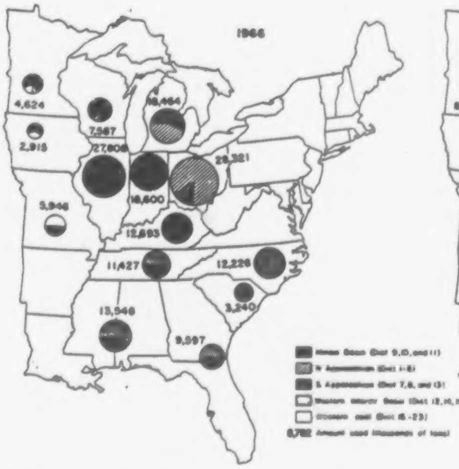

1966
4,624
7,987
18,464
2,915
27,808
28,321
18,600
3,946
12,893
11,427
12,226
3,240
13,946
9,997
8,782

Fig. 3 - Coal consumption by electric utilities in selected states in 1966, by source of coal used. (Source of data: U.S. Bureau of Mines, 1967.)

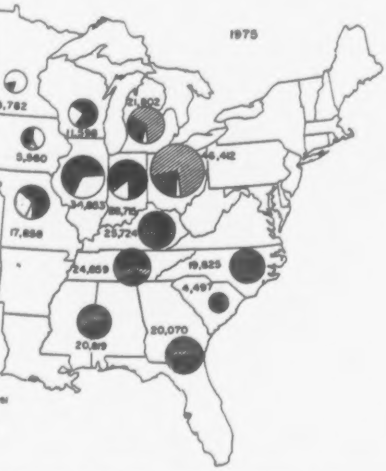

1975
8,782
11,596
21,802
5,960
46,412
34,853
28,75
17,886
25,724
24,859
19,825
4,497
20,070
20,819

Fig. 4 - Coal consumption by electric utilities in selected states in 1975, by source of coal used. (Source of data: U.S. Bureau of Mines, 1976b.)

Source: Ramesh Malhotra and Jack A. Simon, Illinois coal: Development Potential (Illinois mineral note 65), November 1976, p. 8

and 1975 (long enough after enactment to begin seeing the effects of fuel-switching from State Implementation Plan (SIP) compliance, but soon enough to avoid adding the impact of the 1971 New Source Performance Standard (NSPS) for SO2). As indicated, western coal made significant gains in market shares in Minnesota, Iowa, Wisconsin, Illinois and Indiana, with minor penetration into Michigan, Ohio, and Missouri. Central and southern Appalachia coal lost ground in Michigan but gained ground in Alabama and Mississippi.

To look at this situation in more detail, table 1 shows the fuel changes in coal-fired power plants in Illinois between 1972 and 1977. In response to the Clean Air Act, Illinois utilities,

TABLE 1: Fuel Changes in Coal-Fired Power Generation Capacity in Illinois (megawatts)

Total Coal-Fired Power Generation Capacity in 1972		16,424
Converted to Low-Sulfur Western Coal by 1977	6,852	
Converted to Low Sulfur Eastern Coal by 1977	351	
Scheduled to Convert to Low Sulfur Coal	1,673	
Maintaining High Sulfur Coal Combustion	5,798	
Conversions to Oil		430
Retirements by 1977		1,320

Source: Form 67, Federal Energy Regulatiory Commission, 1977. Table adapted from Boyce, et al.

particularly Commonwealth Edison, overwhelmingly chose to switch to Wyoming and Montana low-sulfur coal, rather than to eastern low-sulfur coal or to install scrubbers.

Hence, it would appear that, if history is any guide to future actions, western low-sulfur subbituminous coal would make significant inroads into the Midwest under acid rain legislation. This is an important consideration: one consulting firm, ICF Incorporated, projects little net employment losses under acid rain legislation, assuming that utilities would not choose subbituminous low-sulfur coals in meeting acid rain reductions. That assumption is disputed by another consulting firm, DRI Inc., which projects significant penetration of Powder River Basin subbituminous coal under such legislation. The implication of this is discussed more fully later.

FACTORS INFLUENCING LOW-SULFUR COAL PRICES

A major determinant of future low-sulfur coal production with or without acid rain legislation is price. When examining coal prices, observers tend to focus on sulfur and Btu content of the coal as the primary variables in determining price. Although these are important variables, other characteristics of the coal and specific users' needs also play an important role. For example, table 2 presents the 1980 delivered prices of coal delivered to the individual states according to sulfur content (lbs. per million Btus). As indicated, while coal prices tend to increase as sulfur content decreases, there are signficant anomalies. These anomalies are the result of factors discussed below.

Table 2

1980 DELIVERED COAL PRICES BY DESTINATION STATE
AND QUALITY CATEGORY IN LBS SO2 PER MILLION BTU
COAL PRICES IN 1980 CENTS PER MILLION BTU
DOT "." INDICATES NO COAL USED OF THAT TYPE

STATE	0-.6	.6-1.2	1.2-1.5	1.5-2.0	2.0-2.5	2.5-3.0	3.0-3.5	3.5-4.5	>4.5
ALABAMA	.	180.5	163.0	154.7	151.0	164.7	145.1	150.2	130.4
ARIZONA	104.2	97.7	169.8	.	.	.	.	.	.
ARKANSAS	.	133.5	.	.	.	.	.	.	.
COLORADO	118.2	84.5	96.8	98.6	.	.	.	.	.
DELAWARE	.	219.8	204.3	173.9	141.3	143.5	143.9	141.4	357.2
FLORIDA	.	188.7	183.3	192.2	200.8	200.7	210.4	179.0	154.4
GEORGIA	157.4	179.0	184.0	130.0	135.8	161.7	160.1	160.5	127.5
ILLINOIS	216.9	198.6	214.5	178.4	140.9	138.8	140.8	137.4	126.3
INDIANA	.	233.1	180.8	140.2	103.3	118.5	123.2	105.5	111.7
IOWA	156.8	129.0	147.7	135.4	176.4	178.4	171.5	156.0	153.2
KANSAS	.	102.3	160.5	.	136.4	146.6	141.4	173.5	97.0
KENTUCKY	.	201.3	145.1	125.6	141.1	135.0	125.3	122.0	108.4
LOUISIANA	.	195.0	193.2	.	.	.	.	.	.
MARYLAND	.	.	178.9	129.9	150.6	150.5	152.0	159.5	155.7
MASSACHUSETTS	.	.	191.3	195.1	194.8	.	.	.	.
MICHIGAN	.	151.6	180.2	172.1	169.4	174.4	173.4	129.9	132.0
MINNESOTA	.	197.7	159.0	101.6	98.7	135.6	174.6	184.7	126.6
MISSISSIPPI	.	242.6	.	186.0	171.0	182.6	170.0	151.0	[illegible]
MISSOURI	104.2	119.4	194.0	121.0	163.0	331.4	147.0	110.0	108.[illegible]
MONTANA	.	98.2	96.3	41.4	68.2	.	.	.	.
NEBRASKA	153.6	105.4	182.9	130.0	145.1	130.9	.	.	.
NEVADA	.	104.4	.	.	.	.	.	.	.
NEW HAMPSHIRE	.	.	.	.	.	162.7	174.1	159.4	.
NEW JERSEY	.	209.0	188.0	181.5	194.5	170.6	160.7	155.5	147.4
NEW MEXICO	.	.	.	55.4	.	.	.	.	.
NEW YORK	.	111.8	113.6	157.9	150.6	150.6	147.2	142.7	140.8
NORTH CAROLINA	.	164.2	149.6	164.2	153.8	158.3	154.2	144.4	144.0
NORTH DAKOTA	.	72.2	67.7	53.2	61.9	56.5	72.2	49.8	.
OHIO	155.9	181.0	163.0	155.2	154.7	138.4	127.2	131.5	139.6
OKLAHOMA	.	123.6	.	.	.	.	.	.	.
OREGON	.	141.2	.	.	.	.	.	.	.
PENNSYLVANIA	.	128.3	107.9	129.5	132.9	123.9	126.4	128.0	154.3
SOUTH CAROLINA	.	146.4	153.1	154.3	161.6	157.0	151.3	147.7	139.0
SOUTH DAKOTA	.	86.9	79.8	86.3	76.5	70.7	.	.	.
TENNESSEE	.	180.0	152.1	140.6	140.0	155.8	152.1	159.3	158.5
TEXAS	218.1	177.0	.	54.4	63.2	70.7	.	.	139.4
UTAH	.	114.0	115.7	.	.	.	.	.	.
VIRGINIA	.	172.1	166.0	174.4	186.9	171.6	170.1	.	.
WASHINGTON	.	.	91.3	94.9	98.6	98.3	.	.	.
WEST VIRGINIA	.	151.2	150.0	172.4	154.3	147.2	134.4	118.7	109.5
WISCONSIN	.	145.0	112.2	118.0	127.8	144.6	147.4	154.6	145.4
WYOMING	.	53.6	56.0	66.1	66.6	77.8	.	.	.

Source: Congressional Office of Technology Assessment

Spot versus Contract Prices

The commercial, non-captive, coal market can be broken down into contract and spot transactions, each with its own market characteristics. 3/ About 80 percent of coal is sold under either a long-, intermediate- or short-term contract. Contracts usually designate the amount of coal purchased annually and, generally, include the following specifications: (1) minimum Btu content per pound of coal, (2) maximum allowable amounts of moisture and ash, expressed as a percentage of weight, and (3) maximum allowable sulfur, expressed either as a percentage of weight, or as pounds of sulfur dioxide per million Btus of coal burned. Most contracts contain penalties to the producers if shipments do not meet specifications. Hence, contracts are used as an instrument of price and volume predictability for producers and coal quality for users. More importantly, they frequently serve as the lynchpin to an entire mining operation, often as collateral that mine developers use to get funding for future operations.

A long-term contract is generally one exceeding 10 years. 4/ These arrangements are usually between large mines and large powerplants, and are expected to extend over the life of the plant. Buyer and seller are also linked by high volume unit train shipments of about 10,000 tons each. Annual shipments can range between one and three million tons.

Intermediate-term contracts are generally associated with older facilities with limited remaining useful life, as such plants have no need for longer-term contracts. Short-term contracts are usually less than five years and fall into a gray area between contract and spot purchases.

3/ Schmidt, Richard A. Coal in America, Coal Week: McGraw-Hill, New York, 1979, pp. 394-398.

4/ Telephone communication with the National Coal Association, April 3, 1984.

The spot market, which provides the remaining one-fifth of sales, is the medium for individual transactions or single purchases. The market is served by small producers which lack the capacity to satisfy large sustained orders. Coal users use the market to round out coal requirements and frequently as a hedge against unacceptable short-term contract prices. In declining coal markets, when spot prices lag contract prices by as much as two to three dollars per ton, this market can be used effectively in negotiating new contract terms. However, if purchasing agents get caught short during an expanding market, they can expect to pay dearly for spot shipments to round out needs.

One negative aspect of the spot market is that limited volume shipments cannot attract unit-train rates, and hence, some of the savings are lost to higher rail rates.

Non-Sulfur Coal Properties

A coal's ash (and its fusion temperature), volatility, moisture, grindability, and other non-sulfur related properties have a substantial impact on a coal's suitability for a specific boiler and its ancillary equipment, and, therefore, affects coal purchasing. Boilers are designed to minimize slagging by controlling furnace temperatures. Hence, the ash fusion temperature of a substitute coal is important in determining the extent to which slagging may be a problem in switching coals. For example, boilers with interior partitions and platen surfaces generally cannot use low fusion coals. Boiler design also accounts for the tendency of ash to foul or abrade tube surfaces.

Volatiles also affect boiler design. The lower the volatile content, the longer the flame length must be in order to achieve complete carbon burnout. Low volatile coals also present flame stabilization problems and higher primary air temperatures are needed to assure stability of ignition.

Unfortunately for the low-volatile portion of the eastern low-sulfur coal industry, most existing eastern boilers are not designed to handle this type of coal. Whether one could blend different volatile percentages to increase the potential for such coal is uncertain.

A coal's properties also have significant impacts on the specifications of ancillary equipment. For example, the number and size of pulverizers necessary is a factor of a coal's heating content, ash and moisture levels, grindability, and fineness. Conveyor and storage systems are affected by the coal's agglomerating and fugitive dust characteristics. Ash and sulfur content influence the design of the plant's particulate removal system. All of these factors must be taken into account when determining the cost of fuel-switching a plant.

Rail Rates

Transportation charges are a major component in the delivered price of coal, particularly western coal delivered to the Midwest. The effect of rail rates and railroad deregulation on the coal industry's ability to expand domestic and export markets is hotly contested.

Each industry is heavily dependent on the other. Without the railroads, coal producers would be isolated from many of their markets. Without coal, some railroads would lose a primary source of revenues. The current debate is focused on whether the railroads have capitalized on the coal industry's dependence and the character of its markets to elevate their rates above those that would prevail if alternative modes of transportation existed.

The interdependence of these two industries is illustrated by coal distribution statistics. For example, from January-September 1983, 59.3 percent of total coal shipments moved by rail. Water transportation ranked second at

15.9 percent, followed by trucks (13.8 percent), and tramway/conveyor and slurry pipelines (10.8 percent). 5/ It should be noted, however, that the percentage of truck shipments could be deceiving since most of these shipments are likely associated with mine-mouth steam electric plants. In terms of costs-per-ton-mile, trucks are not economic for more than short distances from mines to receiving facilities.

For the railroads, estimates by the Association of American Railroads (AAR) indicate that coal accounts for 41 percent of the railroad industry's tonnage and 24 percent of its freight revenues. 6/

Both the National Coal Association (NCA) and the AAR have issued studies supporting their respective positions on rail rates. The NCA believes that the Interstate Commerce Commission (ICC) has not protected captive shippers as mandated under the Interstate Commerce Act (as amended). NCA focuses on four areas where it finds shortcomings with recent ICC rulings: (1) market dominance, (2) exemption from regulation, (3) rate guidelines, and, (4) revenue adequacy. Regarding coal rates, the NCA charges that from 1976 to 1981, railroad coal rates rose 40 percent in constant dollars while the minemouth prices of coal dropped 18 percent. It further states that railroad profits from coal are 75 percent higher on a per-ton carried basis than for all railroad freight. 7/

5/ Department of Energy. Coal Distribution, January-September, 1983. DOE-EIA-0125 (83/3Q), p. 1.

6/ Association of American Railroads. Railroad Coal Rates: The Facts. Economic and Finance Department, Washington, D.C. June 1983, p. 2.

7/ National Coal Association. Revised Policy Issues Book, January 9, 1984, section 9-A.

In rebuttal, the AAR states that from 1971 to 1982, the price of coal increased 32 percent in constant dollars while rail coal rates over same period declined 10 percent from the 1971 rates. 8/

Worthy of note is the different periods covered by each of the trade associations. The NCA cost figures for coal and rail rates covers the period from 1976 to 1981 while those of the AAR covers the period 1971 to 1982. This time difference supports the claims of each association, and for logical reasons. In 1971, rail rates were fully regulated by the ICC and energy prices were relatively cheap. In 1974, the Arab oil embargo raised the cost of oil dramatically and the value of energy generally, but rail rates were still regulated. In 1976, the Railroad Revitalization and Regulatory Reform Act (the 4-R Act) was enacted which began the process of rail rate decontrol. Finally, in 1980, this process of decontrol was expanded by enactment of the Staggers Rail Act of 1980. Hence, the period 1971 to 1982 maximizes the effect of events on energy prices while diluting the impact of deregulation, while the period 1976 to 1981 maximizes the effect of deregulation on rail rates while diluting the impact of the first embargo on energy prices. Which baseline is correct depends on one's view of which trend (rising energy prices from periodic oil shortages or rising rail rates from deregulation) will dominate in the future.

In August 1983, the Energy Information Administration prepared its own assessment of rail deregulation impacts on the coal industry. In summary,

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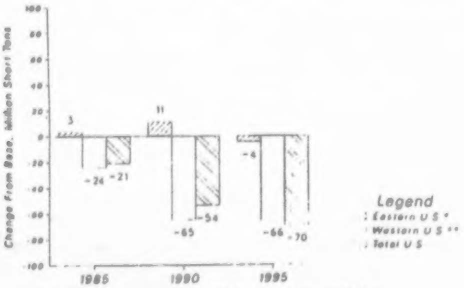
8/ Association of American Railroads. Railroad Coal Rates: The Facts. Economic and Finance Department, Washington, D.C. June 1983, p. 2.

EIA concluded that projected rail rate increases could slow the growth for U.S. coal exports under a scenario based on adequate rail revenues. 9/ Rate increases in excess of revenue adequacy could actually decrease the U.S. share of the future world coal market, although railroad gross revenues would continue to growth substantially. 10/

The domestic market could likewise be adversely affected by rising transportation rates. EIA suggested that, wherever possible, shippers could be forced to use alternative modes of transportation, purchase coal from other suppliers, or switch to other fuels. As shown in figure 5, these increases primarily affect western coal production, which is very dependent on rail transportation and where transportation is the major cost component of delivered price.

Figure 5: U.S. Coal Production, Revenue Adequacy Case
(Change From Base)



Notes: Includes bituminous coal, subbituminous coal and lignite
Totals may not equal sum of components due to independent rounding
Revenue adequacy rate increases: 1985 is 29 percent, 1990 is 71 percent, and 1995 is 90 percent
* States east of the Mississippi River
** States west of the Mississippi River
Source: Energy Information Administration's Coal Supply and Transportation Model projections

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9/ Revenue adequacy is a concept of pricing that, in effect, permits the railroads to establish rates now that will compensate them for revenues lost under the previously regulated system.

10/ Energy Information Administration. Railroad Deregulation: Impact on Coal. DOE/EIA-0339, August 1983.

However, for many utilities and shippers, there are no economic transportation alternatives to rail for at least part of the distance from the mine to end user. Most mines are served by only one railroad, and mines not adjacent to navigable waterways would have to truck their coal either directly to market or to the nearest barge loading facilities. Trucking coal for more than a short distance can become prohibitively expensive. Likewise, the coal has to be moved from the barge terminal to the end user. Also, the waterway has to go where the end users are. Finally, there has been a recent effort by some railroads to diversify into alternative transportation modes, particularly barges. For example, the CSX railroad recently proposed to buy the American Commercial Barge Lines, one of the largest coal carriers. If the regulatory agencies allow further horizortal integration, barging coal to market may no longer be a competitive option to rail.

The NCA has estimated that approximately 85 percent of coal mines are captive to a single railroad. 11/ According to the NCA survey, captivity was higher in the West and in Appalachia where 98 and 95 percent, respectively, of mines depended on a single rail carrier. Only in the Midwest, where operators have greater access to waterways, did the estimate drop to less than 60 percent. These figures probably represent maximums and would be disputed by the railroads.

Impact of rail rates on intermodal coal movements was suggested in EIA's analysis of railroad deregulation. 12/ It projected that if rail rates

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11/ Testimony of Carl Bagge, NCA President, before the Senate Surface Transportation Subcommittee, Hearings on the Staggers Rail De-Regulation Act June 11, 1979.

12/ Energy Information Administration. Railroad De-Regulation: Impact on Coal, DOE/EIA-0399, August 1983, p. 29.

rise 150 percent, significant losses for all modes of coal traffic could occur by 1990. Based on their projections, it seems reasonable to assume that if total coal consumption declines because of higher rail rates, then competing modes of transportation are not economically viable alternatives, and coal users must be fuel-switching—suggesting significant captivity of coal by the railroads.

The magnitude of rail deregulation effect on the overall coal market is debatable, depending on a host of possible scenarios. However, it is noteworthy that at least one utility in Florida is importing South African coal —a decision presumably reflecting comparative delivered costs, including transportation.*

FUTURE DEMAND

Projecting future demand is a risky business. Instead of attempting to specify future production levels, this section focuses on current trends with some quantification where appropriate to support those trends.

Steam Coal

The steam coal market for low-sulfur coal consists primarily of utility, industrial, and export demand. Because of the current uncertainty regarding industrial SO2 emission regulations, no attempt has been made to determine trends in the industrial market. The other two markets are discussed below.

Utility Demand. From 1971 to 1977, the future of Eastern low-sulfur coal looked bright. Markets were expanding in response to State Implementation Plans, and the 1971 New Source Performance Standards provided a significant incentive for utilities to choose low-sulfur coal. Most utilities strenuously opposed EPA's attempts to encourage use of FGD. However, since 1977, this new plant market for compliance coal has almost dried up as the 1977 Clean Air Act amendments required a percentage reduction in emissions regardless of sulfur content (although low-medium sulfur coal has done reasonably well, however, as operators attempt to optimize coal price and plant operations and maintenance costs). Also, low electricity demand has slowed the construction of new plants.

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*Telephone conversation with the National Coal Association, April 5, 1984

Current construction plans by utilities do not suggest a massive increase in eastern bituminous coal demand over the next ten years. According to the North American Electric Reliability Council's 1983 forecast, 1992 eastern coal production consumed in the eastern five NERC regions will be about 100 million tons over 1982 production, assuming all the East Central Area Reliability Coordination Agreement (ECAR) region uses eastern coal, which is unlikely. If only those plants currently under construction are completed by 1992, the increased production would be closer to 70-75 million tons. 13/

Much of this projected increase will be due to greater utilization of existing plants, not new plants. To the extent that these plants are required to burn compliance quality coal (i.e. 1.2 lb. of SO2 per mmBtu or less), low-sulfur coal production will increase over 1982 levels. By the same token, to the extent that the new plants under construction are under the 1971 NSPS (which mandated a 1.2 lb. of SO2 per mmBtu performance standard) instead of the 1978 NSPS (which mandated a percentage reduction in SO2 emissions regardless of sulfur content), the likelihood that they would use compliance

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13/ North American Electric Reliability Council. Electric Power Supply & Demand: 1983-1992. July, 1983.

coal instead of scrubbers is increased. It is unlikely that many of the post-1977 plants would be planned to use compliance coal, given current market conditions and the percentage reduction requirement.

Export Demand. Almost all forecasts of steam coal export demand project significant increases by the year 2000. This demand will probably be for low-sulfur coal since many Europeans countries have chosen clean coals over scrubbers to lower their SO2 emissions. This overseas environmental policy has had a devastating effect on exports of high-sulfur coal produced in the Midwest. However, much of this demand could be satisfied by exports of low-sulfur Appalachian coal if the price is right. Currently, the U.S. is the coal supplier of highest price in most international markets. Despite this, the U.S. will probably be assured part of the world market. A viable industry in each exporting country means diversity of supply for importers. For that luxury, importers have demonstrated a willingness to pay higher U.S. prices. Also, the U.S. has the capability of responding quickly to surges in demand.

However, if the United States intends to capture a larger share of future world markets, its coals must become more economic through reduction of mining costs, inland transportation freight rates, or ocean borne shipping charges. Time could also be a crucial element in even maintaining current market share. The People's Republic of China and other countries such as Colombia possess considerable coal reserves, much of which is low-sulfur. Currently, the weak link in these countries' export capacity is inland transportation. Time and investment will strenghten that link. Investments are already being made, some by major U.S. customers (such as Japan), and others by American firms. When these countries enter the market, world demand would be divided again, to maintain diversity of supply. These developments may have a direct bearing on future eastern low-sulfur coal demand.

Metallurgical Markets

The market for metallurgical coal has been a mainstay of the eastern low-sulfur coal industry. Current projections of demand for metallurgical coal are not promising. The current downturn in domestic steelmaking has depressed domestic metallurgical coal demand, driving up miner unemployment, particularly in southern West Virginia. Projections by Data Resources Incorporated presented in table 3, indicate that it may be 1995 before the 1981 metallurgical coal production levels of 1981 are achieved again in terms of domestic demand and exports.

Table 3: Projections of Metallurgical Coal Market
(millions of short tons)

	Actual		Projection		
	1981	1982	1985	1990	1995
Domestic Consumption	61.0	43.1	54.6	57.7	62.4
Exports	65.2	64.6	60.0	62.0	65.0
Total Production	126.2	107.7	114.6	119.7	127.4

SOURCE: DRI, 1983.

Besides the current downturn in steel production, there is a systemic reason for the projected trend in the metallurgical coal market: technological improvements by iron foundries and the steel industry have steadily reduced the average amount of coke necessary to produce iron casting and steel. In particular, the increasing use of electric furnaces requiring no metallurgical coal is expected to continue, as shown in table 4. Hence, even if steel demand recovers, metallurgical coal production might still not return to its earlier levels by 1995.

For the export market, sluggish demand for steel by countries using U.S. metallurgical coal, technological improvements in coke utilization, and little displacement of oil in iron and steel furnaces by coking coal is expected to constrain demand. 14/

For a significant increase in metallurgical coal demand to occur, there must be a substantial increase in domestic or foreign coking operations dependent on U.S. metallurgical coal. This would have to be preceded by an increase in domestic or foreign steel made with U.S. coal.

Table 4: Steel Furnace Share of Production*

TYPE OF FURNACE	1982	1985	1990
Basic Oxygen	62.0%	62.4%	62.4%
Electric	30.0	29.1	33.7
Open Hearth	8.1	8.2	3.9

*Columns do not total because of rounding.
Source: DRI. Energy Review, 1983.

14/ Data Resources, Inc. Energy Review, Spring 1983.

ACID RAIN LEGISLATION AND THE EASTERN LOW-SULFUR COAL INDUSTRY

Bills designed to mitigate acid rain fall into three categories: (1) research only, (2) research and mitigation of impacts, and (3) reductions in SO2 and sometimes NOx. It is the last category which could have a significant impact on the coal market. There are currently about a dozen bills introduced to reduce SO2 emissions by between 8 and 12 million tons annually. While each of these bills would reduce SO2 emissions by one-third to one-half from current levels, their impact on the coal market varies substantially more because of differences in how the reductions would be achieved. This section analyzes potential impact of twelve of these bills by (1) describing the bills and provisions for protecting high-sulfur coal, (2) estimating the production impact of such bills on low-sulfur areas, (3) estimating price increases for low-sulfur coal, and (4) analyzing critical issues raised.

SO2 REDUCTION BILLS

SO2 reduction bills can be cross-categorized by their reduction requirement (i.e 8, 10, or 12 million tons) and whether the bill contains any revenue raising provision. As discussed below, the non-revenue raising bills generally would have the greatest impact on the coal market as polluters are assumed to be free to coal-switch as economics dictate. The primary purpose of the revenue-raising bills is to provide incentives to prevent or mitigate disruptions in the coal market. The effectiveness of these provisions is assessed later.

Non-Revenue Raising Bills

Seven bills fall into the non-revenue raising category: (1) H.R. 132 (Gregg, R-N.H.), (2) H.R. 2794 (St. Germain, D-R.I.), (3) S. 145 (Mitchell, D-Maine), (4) S. 768 (Stafford, R-Vt., as ordered reported by Senate Environment and Public Works Committee, (5) S. 768 (as initially introduced by Stafford, R-Vt.), (6) S. 769 (Stafford, R-Vt.), and (7) H.R. 3251 (D'Amours, D-N.H.). The first four are basically 10-year, 10 million ton reduction bills within the Eastern 31 States. These four bills do not limited control methods, but S. 145/ H.R. 2794 does require that sources meeting the reduction requirement by fuel-switching to do so within 6 years, instead of 10 years. H.R. 132 requires that reductions be substantially completed within 8 years. The recently reported S. 768 required fuel-switching compliance within 5 years. The potential impact of these interim deadlines on coal prices is discussed later.

As introduced, S. 768 was identical to S. 3041 from the 97th Congress as reported out by the Senate Environment and Public Works Committee. Basically, it required an 8 million ton reduction by 1995, and like S. 145/H.R. 2794, it required that sources meeting the reduction requirement by fuel-switching to do so within 6 years. Senator Stafford's other bill, S. 769, would increase the reduction requirement to 12 million tons by 1998, while keeping the interim 6 year deadline for sources choosing to fuel-switch.

The final bill, H.R. 3251, does not specify a precise reduction requirement but the intent is to achieve reductions in the 10 million ton range. There is special emphasis in the bill for the 50 largest utility emitters of SO2 to reduce emissions to 15 percent of their 1980 levels. The intent is to encourage the use of FGD on these plants instead of fuel switching without mandating such technology. If successful, this provision would save a significant portion of the high-sulfur coal industry's production.

Revenue-Raising Bills

Five bills fall into the revenue-raising category: (1) H.R. 3400 (Sikorski, D-Minn.,Waxman, D-Calif.), (2) H.R. 4404 (D'Amours, D-N.H.), (3) S. 2215 (Glenn, D-Ohio), (4) S. 2001 (Durenberger, R-Minn.), and (5) H.R. 4483 (Aspin, D-Wis.). The first three bills propose either a regional or national tax on electricity generation to fund installation of technological SO2 control, such as FGD. H.R. 3400's 1-mill fee on non-nuclear generation within the contiguous 48 States would fund 90 percent of the capital cost to scrub the top fifty utility emitters of SO2. This requirement would provide about 6.6 million of the 10-year, 10 million ton reduction requirement and protect the high-sulfur coal being delivered to those plants. The remaining 3.4 million tons would be achieved through whatever means States chose to employ.

The second bill, H.R. 4404, is derived from H.R. 3400, but involves a 12 million ton reduction by 1995. H.R. 4404's 1.5 mill fee would be levied on fossil-fuel fired power plants with an exemption for low-income households. The bill retains the Top-50 requirement of H.R. 3400, but adds two million tons of SO2 to the reduction requirement to be achieved by reductions in industrial emissions. The 5.4 million tons required in addition to the Top-50 to obtain the reduction target would be achieve though whatever means States chose to employ.

S. 2215 is the final generation tax bill. This proposal calls for a phased-in 3-mill per kwh fee on all fossil-fuel fired generation within a 31-State region to finance an 11-year, 8 million ton reduction in the Eastern 31 States. The fee would fund 90 percent of the capital costs and 50 to 90 percent of the operations and maintenance costs for technological control strategies. The proposal also contains very strong provisions against fuel switching to achieve the reduction goal.

The second revenue raising approach is through a SO2 tax. The concept of using a SO2 tax to reduce emissions of that pollutant is not a new idea. In the early 1970s, the Nixon Administration recommended such a tax to provide economic incentives to polluters to reduce their emissions. Ideally, such a tax would be set at the marginal cost of reducing SO2 emissions to the desired level. This would result in polluters finding it cost-effective to reduce their emissions to avoid paying the tax. Hence, the purposes of the tax would not be to raise revenue per se (although it would) but to induce reductions at minimal costs.

H.R. 4483 is somewhat similar to this approach. The bill would impose a $0.50 a lb. (roughly $526 per ton of SO2) on the sulfur content of coal, with rebates for those facilities employing reduction techniques. High-sulfur coal protection consists of a 90 percent subsidy of costs for installing technology on power plants in response to the bill. However, unlike H.R. 3400 no one is forced to accept the technology or the subsidy.

An approach entailing use of a sulfur emission tax specifically as a revenue device to fund reductions is S. 2001. The bill would establish a nationwide tax to raise $40 billion over a 10-year period to pay for up to 70 percent of the capital costs and 30 percent of the O & M costs for a 10-year, 10 million ton reduction in SO2 in the Eastern 31 States. Effective protection of high-sulfur coal production consists primarily of administrative discretion to prevent fuel-switching when great miner unemployment/dislocation is anticipated. "Great" is not defined.

METHODOLOGY

In discussing acid rain legislation, it is important to remember that that most of the bills have compliance deadlines of 5 to 12 years. This leadtime makes any projection of coal production impacts very uncertain. Indeed, it is suggested that the reader concentrate on the economic approach taken in the projections, the direction of production shifts, and the magnitude of the production increases/decreases rather than focusing on the absolute totals. Modeling is important for the insight it can provide one in analyzing a question. It is not a crystal ball.

The projections used in this report use a least-cost methodology in determining utility choices implementating an acid rain program, except where choices are restricted by the specific program. This methodology generally assumes non-random behavior by utilities in choosing the least expensive control method (i.e. no decisions based on political or other non-economic considerations). However, within this least-cost methodology, there are at least three approaches to modeling the dynamics of the coal market and determining the demand and price of eastern low-sulfur coal: (1) cost-based approach, (2) historical-based approach, and (3) rent-based approach. The following discusses the three approaches, along with their strengths and weaknesses.

Cost-based Approach

A cost-based approach attempts to estimate the price of coal by examining the cost of producing it. Basically, this approach assumes that buyers have already contracted for most production at full costs, and hence, new contracts will be made at the current marginal cost of production. Producers are assumed to require only a fair rate of return, and not exploit any potential market advantages presented by any increase in demand or their position in the market.

Given that coal markets are assumed to be competitive and coal firms profit maximizing, this approach involves developing the marginal cost of production for different production levels. For coal, this endeavor would require at least estimates of the exploitable reserve base, mining costs, preparation costs, and transportation costs. Depending on the accuracy and detail required, this can be quite difficult. For example, as shown earlier, the reserve base can be divided according to sulfur content, ash content, coking ability, Btu content, and various other characteristics which influence its cost to mine and its value in the market. The result of this effort would be cost supply curves, broken down according to whatever category was considered appropriate for the analysis.

The primary model employing this method and making acid rain projections is ICF's Coal and Electric Utilities Model (CEUM) 15/. The model is detailed, but fairly straightforward. Basically, an exogenous electricity demand is satisfied through a supply component and transportation network at least-cost. Supply and demand are balanced through a standard linear programming formulation for each of 43 coal-types. Production-related output is reported by (1) 38 CEUM supply regions, (2) 12 aggregations of supply regions, (3) four broad geographic regions, and (4) national totals. Consumption-related output is reported by (1) 45 CEUM demand regions, (2) nine aggregated demand regions, (3) three broad geographic regions and (4) national totals. Other detailed breakdowns are available.

The CEUM model and the theory behind it are based on some critical assumptions about the nature of the coal market, coal demand, and the behavior of its participants. First, the theory being employed assumes

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15/ This model is ICF's refinement of the National Coal Model which is used by the U.S. Department of Energy. Generally, the discussion here is relevant to that model as well as for CEUM.

a basically competitive market for coal where price is equal to long-term marginal cost. While the CEUM employs numerous constraints to include various technical, institutional and regulatory considerations, it assumes that no one supplier, transporter, or state government or groups thereof have sufficient market dominance to dictate price to a buyer (i.e. a utility). For example, ICF's current (October 1983) thinking on coal transportation is to assume a greater degree of competition than in previous projections. This assumption results in projections of marginal cost in the future at 95 percent of current average rates. This projection puts the transporation section marginal revenue roughly at the level of their variable costs and hence, represents the minimum price a railroad should be willing to accept to avoid losing a route.

This assumption is disputed by other forecasters. For example, in a recent report, DRI assumes that rail rates will raise to 180 percent of variable costs, with a low rate scenario of 140 percent of variable costs. 16/ DOE's Energy Information Administration (EIA) analysis of acid rain legislation used a 3 percent annual real increase in rail rates as its base case, with higher rates used for sensitivity analysis. 17/

The degree to which the competitive assumption is correct depends on the market dominance of participants and market barriers to new entry. The ICF model assumes that in the long-run, these problems will disappear and the market will achieve equilbrium. Indeed, the model's movement toward equilbruim is constrained primarily by technical and contractual barriers placed

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16/ Data Resources Inc. Assessing the Impacts of Proposed Acid Rain Legislation. December 14, 1983.

17/ Energy Information Administration. Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries. 1983 in the model. Generally, in analyses of acid rain legislation, the model has generally assumed that compliance deadline is sufficently far off to eliminate most current constaints to fuel switching, particularly in its most recent analyses which delay compliance until 1995. 18/

This assertion that acid rain legislation is sufficiently long-term to eliminate short-term imperfections in the market place is heavily dependent on the time frame analyzed and the competitive nature of the particular industry. The interim deadlines calling calling for fuel-switching to be made within 5-6 years cast some doubt on the industry's ability to respond in a orderly fashion. Whether the coal supply chain is competitive is disputed, and is discussed further under the rent-based section.

A second aspect of the model is that while price is important in determining the coal supply available and the control method chosen in CEUM (including type of coal), price has little or no effect on the actual overall demand for coal in some sectors (industrial, non-industrial, and exports), or related services which use coal (such as steelmaking). For example, as the price of coal rises in response to acid rain legislation, export sales are assumed not to suffer. Such demands are considered inelastic. This lack of price interaction with service demand results in coal production gains or losses from acid rain legislation simply being added to production gains or losses resulting from growth which is assumed to occur without the program. This growth is assumed not sensitive to the coal market's reaction to acid rain legislation. The extent to which this is true depends on the increase in coal prices resulting from the legislation.

18/ For example, see ICF Incorporated. Memorandum to Alliance for Clean Energy. September 22, 1983.

Historically-based Approach

Historical approaches view the past as the best indicators of the future. This conservative approach to projecting the future is the opposite of the previous approach where the future is forecasted based on current knowledge of future activities and economic trends such as depletion of reserves, competition in transportation, and coal production. Rather than speculate on the future dynamics of these sectors, a historical approach looks at the dynamics as they are currently being played out and assumes that they will continue in that equilibrium in the future. Hence, rather than forecasting the future, an historical approach takes past trends and uses them to project future dynamics.

In modeling acid rain scenarios, the Congressional Office of Technology Assessment and Peabody Coal Company are the primary groups using a historical approach to projecting coal production shifts. Using the AIRCOST model developed by E.H. Pechan and Associates, OTA uses 1980 coal market conditions as the basis of its analysis. 1980 might be characterized as a "normal" year in the coal industry in that there was no general UMWA strike or major recession, although there was disruptions in the oil market.

To achieve mandated reductions under an acid rain bill, the AIRCOST model employs a least-cost methodology using levelized costs. SO2 control alternatives in the model include blending, switching, cleaning, wet and dry scrubbing, or any combination thereof. Decisions are made on a unit by unit basis, not for an entire site. To determine the various alternative coals available for a State's utilities, the model rank orders currently delivered coals to the State according to 1980 delivered price, Btu content, and sulfur content. For States which do not have a complete range of alternative coals, data from surrounding States is modified to reflect costs if the coal had been delivered to that State. Coal and transportation costs are assumed at their 1980 levels.

Peabody Coal Company uses a fairly simple approach in determining production impact. Basically it compares the costs of fuel-switching a specific plant to low sulfur coal compared with an assumed cost for FGD. If it is cheaper to switch, the company assumes the plant will switch. However, Peabody Coal has focused its analysis on job losses resulting from acid rain legislation, and not job creation in low-sulfur coal areas. Hence, its projectons are not relevant to this analysis.

The critical assumption of the historical approach is obvious: future coal markets are assumed to operate as they currently do. This minimizes speculation about the dynamics of future coal markets. No assumption about future growth is required. The approach also captures the nature of the coal industry and transportation rates as they are reflected in current delivered prices. Hence, any rents currently acruing to parties are assumed to continue being allocated to those parties.

The extent to which the above assumption is correct depends on three variables. First, the year chosen (1980) must indeed be representative of current dynamics in the coal markets. Second, the impact of acid rain legislation must be sufficently short-term (or current market dynamics sufficiently long-term) that current coal market dynamics are a reasonable indicator of the coal market's reaction. Third, acid rain legislation must not per se result in a fundamental change in the dynamics of the coal market.

Rent-based Approach

The rent-based approach disagrees with the competitive market assumptions of the cost-based method. Basically, this approach sees demand for low-sulfur coal as fairly inelastic and assumes that there are those in the coal supply chain in a position to exert market power to raise prices in response to any sudden increase in demand for low sulfur coal resulting from acid rain legislation. The approach does not suggest that more or less fuel switching would occur under such conditions than that projected by other approaches, but only that the cost to consumers may be much higher.

Assuming no restrictions on fuel switching, acid rain legislation would create a premium on low-sulfur coal that would be captured by those participants in the coal supply chain having the market position to influence prices. This premium (also called an economic rent, producer surplus, monopoly profit, or windfall profit) is assumed in the cost-based studies to be allocated to electricity consumers in terms of lower rates in comparison with other alternative reduction strategies. The rent-based approach argues that rent will accrue to other participants in the coal supply chain before it gets to the consumer. This is believed to be occurring with respect to some western coal. As assessed by Martin Zimmerman of MIT:

> Those with the most favorable market positions are the railroads and state legislatures. The state legislatures can, by raising taxes, apropriate rents. Railroads, by raising rates, can also take advantage of the less elastic demand. Both groups have realized this. Railroad rates have increased rapidly in the last few years and the evidence is that this is in response to changed market circumstances. State legislatures have raised their taxes, particularly in Montana and Wyoming. 19/

19/ Zimmerman, Martin B., and Alt, Christopher. The Western Coal Tax Cartel. Revised January 1981.

Indeed, Zimmerman's work suggests that the optimal tax rate for Montana-Wyoming in collecting these rents would be about 62.5 percent. While this seems very high, Zimmerman suggests that is not when compared to the actions of the railroads:

> A tax of over 60% sounds high. However, when considered in terms of what the railroads have been doing, a 62.5% tax is not high. Western coal is transport-intensive because of the large distances to major demand centers. Transport cost accounts for a large proportion of the delivered cost of Powder River Basin coal. If one temporarily assumes that the rents go exclusively to the single railroad originating coal in the Powder River Basin, one may estimate the increase in railroad tariff that is comparable to different severance taxes. The 62.5% tax is equivalent to a charge of roughly $4 per ton in 1980. Current tax levels of 16.8% account for approximately $1 of that. Thus, the difference btween today's level and the "optimum" amounts to about $3.00 per ton. That figure represents 16% to 24% of the transport cost to Chicago. Recent increases in rail rates are an attempt by the railroads to capture some of this rent. 20/

Under acid rain legislation, transporters in the East would probably be in the best position to capture rents. Eastern State governments (West Virginia and Kentucky) would probably be constrained from raising severence taxes significantly as they would hurt their high-sulfur coal industry even more than anticipated under the legislation.

Transporters in the East have the advantage that their transportion cost component of delivered coal is much less than that of western coal transporters. Eastern coal is much more expensive to mine than western coal and distances to powerplants are less than in the west. A recent DOE study on S. 3041 did a sensitivity analysis on coal production shifts occuring under three different transportation cost escalations: 3 percent annually, 8 percent annually, and 12 percent annually. As shown in

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20/ ibid.

Table 5: U.S. Bituminous Coal and Lignite Production--Base Case and Sensitivity Cases, With S.3041, 1995
(Million Short Tons)

		With S.3041			
		Transportation Cost[a]		Electricity Demand	
Region[b]	Base Case	5%	9%	Low	High
Northern Appalachia	203	207	211	200	199
Central Appalachia	439	430	401	386	444
Southern Appalachia	31	41	47	31	30
Midwest	111	146	179	113	108
Central West	23	30	53	21	25
Gulf	102	102	103	102	102
E. Northern Great Plains	36	40	29	31	31
W. Northern Great Plains	247	180	119	232	288
Rockies	57	53	52	50	83
Southwest	61	60	63	55	58
Northwest	6	12	14	6	9
Total	1,316	1,301	1,271	1,226	1,377

[a] Compounded annually.

[b] See Figure 6 for definition of regions.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

table 5, central Appalachia coal production only decreased 2 percent from the base case to the 8 percent case while the Northern Great Plains production dropped 22 percent (although some switching between different sulfur categories may have occured in central Appalachia). As would be expected, much of the western coal losses were to the Midwest, where utilities found it cheaper to revert to local coals and scrub rather than pay higher transportation costs. The same did not occur to nearly the degree with central Appalachia where northern Appalachian utilities' evidently still found it cheaper to switch than to scrub local coals.

The critical assumption of this approach is that these participants would be able to collect the rents resulting from acid rain legislation.

Recent acquisitions by and mergers of major rail carriers could enhance their capability to extract rents resulting from acid rain legislation. Recent events suggesting more horizontal intergration of Eastern transporters include Norfolk Southern and CSX discussions over control of Conrail and CSX's attempt to purchase American Commercial Barge Line. However, unlike the other two approaches discussed here, no formal projections of acid rain program costs under a rent-based approach have been conducted.

IMPACT ON EASTERN LOW-SULFUR COAL REGIONS

Unfortunately, analyses of coal production have been fairly piecemeal over the last two years with no comprehensive range of different scenarios and implementation strategies examined. ICF has done the most complete set of modeling runs, but under differing assumptions and timeframes that limit the validity of comparisons. Within this constraint, this section presents the various analyses conducted in terms of production shifts and price changes.

Production Shifts

ICF, DRI, DOE, Peabody Coal and OTA have all conducted analyses of at least one acid rain bill. However, no comprehensive analysis of all the bills has been done by one modeler using the same assumptions. Some of the bills have provisions which are difficult to quantify such as offsets for future growth of emissions. Hence, a 10-year, 10 million ton reduction may be a 10-year 8, 10, or 11 million ton reduction depending on one's view of future emission increases and the bill's treatment of SIP required reductions. This analysis presents a range of possible interpretations of the bills.

Also, the data presented by the models are generally in the form of regions (i.e. central Appalachia) rather than by sulfur content. Central Appalachia contains coal beds of several sulfur contents, not only compliance quantity. Where possible, such data are broken down into sulfur content.

S. 768 (as introduced). S. 768 is the direct successor to S. 3041 and, as such, is the most studied acid rain bill. ICF, DRI, and DOE have all done analyses of the bill under different assumptions. Table 5 summarizes their results. ICF indicates the greatest amount of regional coal shifts while DRI indicates the least amount. There are several possible explanations for this. First, ICF does not permit shifting of coals from boilers designed for bitimunous coal to subbituminous (i.e. western Powder River coal) coal. Secondly,

Table 5: Production Changes from 1995 baseline
resulting from S. 768
(millions of tons)

Region/State	Model ICF	 DRI	 DOE
	REGIONAL DATA		
Northern Appalachia	(58-72)*	(22)	(39)
Central Appalachia	52-66	35	93
Southern Appalachia	0	n/a	(3)
Midwest	(77-93)	(28)	(87)
West	81-95	n/a	56
	CENTRAL APPALACHIA STATE DATA		
Southern West Virginia	27-36	n/a	n/a
Virginia	6	n/a	n/a
East Kentucky	21-24	n/a	n/a
Tennessee	(1)-1	n/a	n/a

* () = negative change in production

Source: ICF, Incorporated. Analysis of a Senate Emission Reduction Bill (S. 3041). Prepared for the U.S. Environmental Protection Agency, February 1983.

DRI Incorporated. Assessing the Impacts of Proposed Acid Rain Legislation, December 14, 1983

Energy Information Administration. Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries, 1983.

costs of retrofitting are assumed to be very modest. Hence, central Appalachian coal is assumed to penetrate westward into the Illinois Basin to the Mississippi River. DRI, however, assumes significant costs for updgrading particulate control equipment for fuel switching and permits the substitution of Powder River Basin coal for eastern bituminous coals. The result is significantly more scrubbing in northern Appalachia and the Midwest and less production increases in central Appalachia than ICF projects. As shown in table 7, while ICF projects significant penetration of Appalachian coal into the Midwest, DRI projects no increased penetration of central Appalachian coal.

Table 7: Production Shifts for Central Appalachian Coal
(millions of tons)

	Model	
Region	ICF	DRI
New England	1.7	7.5
Middle Atlantic	11.5	0.0
South Atlantic	21.2	20.6
East North Central	22.3	0.0
East South Central	4.5	6.7
West Bank	0.0	0.0

Source: ICF, Incorporated. Analysis of a Senate Emission Reduction Bill (S. 3041). Prepared for the U.S. Environmental Protection Agency, February 1983.

DRI Incorporated. Assessing the Impact of Proposed Acid Rain Legislation, December 14, 1983.

The DOE model run compounds the fuel-switching tendencies of the CEUM-NCM model with uniformly increasing rail rates to produce a very high production increase for central Appalachia. Also, the NCM apparently permits some minemouth capacity to fuel-switch.

Only ICF broke the increased demand according to State area. While southern West Virginia is projected to rise 27 million ton under acid rain, northern West Virginia is project to fall 9 million tons. This 9 million tons does not include the roughly 4.5 million tons which would be lost to Canada under acid rain. Hence, the net increase for the State would be 13.5 million tons assuming no other changes in the export or metallurgical markets.

For Kentucky, the losses in western Kentucky are projected to exceed the gains in eastern Kentucky by 6 million tons.

S. 2215. No comprehensive analysis of the coal production impacts from S. 2215 has been conducted. However, given the large subsidies given utilities who choose to install control technology and the strict requirements for those utilities seeking to fuel-switch, it is unlikely that the bill would cause a significant shift in the market.

H.R. 132, H.R. 2794, S. 145, S. 768 (as reported), and S. 2001. These bills are all 10-year, 10 million ton bills, generally involving some kind of offset provision. The first four have no revenue raising provisions to finance technological control methods, and mitigate the production shift. S. 2001 has a revenue raising provision but it does not per se mitigate production shifts. It is assumed here that the Administrator under S. 2001 does not exercise the authority to mitigate such impacts.

Intepretation of these bills have resulted in analyses of 8, 10, 11 and 12 million ton scenarios. Most of the analyses done on these bills were done on predecessors with a 1990 deadline. As the deadline changes, the potential for fuel switching increases, as contracts play out and plants age. Recent analysis by ICF assuming a later deadline is used to illustrate this point in Table 8.

Table 8: Production Shifts under 10 year, 10 million ton Reduction Bills
From 1990 and 1995 Deadlines
(millions of tons)

	1990 Deadline				1995
REGION	8.1	10.0	11.1	12.0	9.5
Northern Appalachia	(33)	(33)	(44)	(43)	(56)
Central Appalachia	47	47	50	50	55
Southern Appalachia	(3)	2	(2)	(4)	1
Midwest	(55)	(58)	(60)	(51)	(99)
West	40	40	56	46	73
Southern West Virginia	21	17	n/a	23	28
Virginia	7	5	n/a	9	6
East Kentucky	22	24	n/a	21	20
Tennessee	(4)	(1)	n/a	(4)	1

Source: ICF Incorporated. Results of ICF Analysis of Alternative Regulatory Approaches to Reduce Emissions of Sulfur Dioxide. Prepared for the Edison Electric Institute, November 19, 1981

ICF Incorporated. Cost and Coal Production Effects of Reducing Electric Utility Sulfur Dioxide Emissions. Prepared for National Wildlife Federation and National Clean Air Coalition, November 14, 1981.

ICF Incorporated. Analysis of a 10 Million Ton Reduction in Emissions From Existing Utility Powerplants. Prepared for the Environmental Protection Agency, June 1982.

ICF Incorporated. Analysis of Coal Production and Employment Impacts of the Waxman-Sikorski Bill and a Cost-Effective Equivalent. Prepared for the Alliance for Clean Energy, September 22, 1983.

Because of the interim deadlines contained in most of these bills, the earlier ICF runs may more accurately reflect production shifts under these bills than the 1995 run. The interesting aspect of the four 1990 runs is the inelasticity of central Appalachian coal demand under different reduction requirements. Despite reduction increases of 50 percent, demand for central Appalachian coal only increases about 5 percent. Of course, the mix of sulfur categories within the central Appalachian region may be shifting under the different scenarios, but the net impact on the region is the same.

A state-by-state comparison of production shifts indicates a fairly even distribution of the coal demand between southern West Virginia and eastern Kentucky. The only exception is the 10 million ton reduction, which is probably because of its interstate trading assumption. For West Virginia, these scenarios result in net gains of between 8-14 million tons, assuming no losses in the export market. For Kentucky, the production increases are very uncertain with a range of 1-19 million tons.

Examining the shifts in central Appalachian coal production by sulfur content indicates that the ICF model is primarily increasing low-sulfur (i.e. compliance coal) at the expense of higher sulfur coals (see table 9). This would suggest that demand for compliance coal would be greater than that suggested by the aggregate central Appalachian coal production figures, assuming ICF is correct. Also, because gross dislocations are more closely related to adverse economic impact than net dislocations, adverse economics impacts would also be greater than suggested by the aggregated figures.

Table 9: 1990 Central Appalachian Production by Sulfur Content
(millions of tons)

	Base Case	11.1 Million ton Reduction Requirement
Low Sulfur	76.1	131.6
Low-Medium	89.9	94.1
High-Medium	46.8	35.7
High	1.7	1.3
Metallugical	77.3	78.6
Total	291.8	341.3

Source: ICF Incorporated. Analysis of a 10 Million Ton Reduction in Emissions From Existing Utility Power Plants. Prepared for the Environmental Protection Agency, June 1982.

ICF's emphasis on compliance coal is disputed by the OTA model of a 10 million ton reduction, as shown in table 10. Basically, the OTA model sees Midwest utilities blending low-medium eastern bituminous coal with low-sulfur western coal to meet reduction requirements rather than buying low-sulfur central Appalachian coal only. By blending these coals, the utility can avoid some of the derating problem involved in using western coal exclusively while taking advantage of the cost advantage of western coals. This places the OTA projection closer to the DRI projection in terms of western coal penetration and lower central Appalachian coal production.

Table 10: OTA Production Shifts for 10 million Ton Reduction from 1980 Baseline (millions of tons)

Sulfur Content (lb./mmBtus)	Production Shift		
	Total	East	West
0.0-1.2	28.9	(5.2)	34.1
1.2-3.0	54.4	54.8	(0.5)
more than 3.0	(50.7)	(50.7)	0
Total	32.6	(1.1)	(33.6)

Source: OTA Oceans and Environment Program. An Analysis of the Sikorski/Waxman Acid Rain Control Proposal: H.R. 3400, "The National Acid Deposition Control Act of 1983" Revised July 12, 1983.

H.R. 3400. H.R. 3400 is currently the acid rain reduction bill receiving the most attention in the House. One of its features is an explicit attempt to protect the northern Appalachian and midwestern high-sulfur coal industry from significant decline by requiring technological controls on the Top-50 utility emitters of SO2. All the previous projections show shifts away from northern Appalachian and midwestern coals from acid rain legislation. The H.R. 3400 technology requirement, accounting for roughly two-thirds of the 10 million ton reduction, is designed to lessen that shift.

Table 11 presents projected production shifts under H.R. 3400 by ICF and DRI. ICF indicates very little shifting of production resulting from the legislation. DRI, however, indicates a

Table 11: Production Shifts under H.R. 3400 for 1995 Baseline
(millions of tons)

REGION	ICF	DRI
Northern Appalachia	(11)	(14)
Central Appalachia	5	17
Southern Appalachia	0	n/a
Midwest	5	25
West	4	n/a
Southern West Virginia	5	n/a
Virginia	0	n/a
East Kentucky	1	n/a
Tennessee	(1)	n/a

Source: ICF Incorporated. Analysis of Coal Production and Employment Impacts of the Waxman-Sikorski Bill and a Cost-Effective Equivalent. Prepared for the Alliance for Clean Energy, September 22, 1983.

DRI Incorporated. Assessing the Impacts of Proposed Acid Rain Legislation, December 14, 1983.

greater degree of shifting although much less than indicated for non-revenue raising bills. This may be due to plants projected to scrub switching to lower sulfur coal to reduce operations and maintenance costs. In either case, H.R. 3400 appears effective in eliminating the projected decreases in midwestern coal production and at least partially eliminating decreases in northern Appalachian coal production.

This is confirmed by the OTA projections, although the shift away from high-sulfur coal is projected to be a little higher. As indicated in table 12, OTA projections still show some blending of western and medium-low sulfur eastern coals, but at a greatly reduced rate.

Table 12: OTA's Projections of Coal Shifts under H.R. 3400 from a 1980 Baseline (millions of tons)

Sulfur Content (lb./mmBtu)	Production Shift		
	Total	East	West
0.0-1.2	12.1	(4.2)	16.3
1.2-3.0	31.3	28.5	2.8
more than 3.0	17.5	(17.5)	0
Total	25.9	6.8	19.1

Source: OTA Oceans and Environment Program. An Analysis of the Sikorski/Waxman Acid Rain Control Proposal: H.R. 3400, "The National Acid Deposition Control Act of 1983." Revised July 12, 1983.

On a state-by-state level, both West Virginia and eastern Kentucky basically break even under the bill with losses in the higher sulfur areas recouped in the lower sulfur areas.

H.R. 4404, S. 869. The uncertainty of projecting the coal production impacts of any major SO2 reduction program is great. The uncertainty of projecting the impact of a 12 million ton reduction is tremendous. Hence, great caution should be exercised in reviewing the numbers presented here.

No studies expressly examining H.R. 4404 or S. 869 have been conducted. However, some scenarios with similar features as these bills have been analyzed. For examining S. 869, a 13.1 million ton reduction by 1990 scenario has been chosen to provide an illustration

Table 13: Production Shifts from 12 Million Ton Reductions (millions of tons)

	Reduction Requirement	
	1990 Deadline	1995 Deadline
REGION	13.1	12.8*
Northern Appalachia	(42)	(19)
Central Appalachia	55	7
Southern Appalachia	(4)	(1)
Midwest	(63)	(11)
West	55	29
Southern West Virginia	n/a	4
Virginia	n/a	2
East Kentucky	n/a	3
Tennessee	n/a	(2)

*Includes subsides for constructing scrubbers.

Source: ICF Incorporated. Summary of Preliminary Analysis of the Costs and Coal Production Impact of the Mitchell Bill. Prepared for the Edison Electric Institute, January 25, 1982

ICF Incorporated. An Analysis of 12-Million Ton SO2 Reduction Alternatives with SO2 Control Technology Subsidies. Prepared for the Natural Resources Defense Council, Environmental Defense Fund, League of Women Voters of the U.S., and the National Wildlife Federation, August 1983.

of the impacts involved with the legislation. It was chosen because S. 869 includes an offset provision, raising its effective reduction requirement, and has a 1990 interim deadline for fuel switching. As indicated in table 13, its projected shifts would be somewhat greater than those projected for the ten million ton programs discussed earlier. However, the uncertainty involved is very great.

To assess the impacts of H.R. 4404, the 12 million ton reduction by 1995 modeled by ICF for the National Wildlife Federation was used. It included a significant subsidy for installing scrubbers. As indicated, the subsidy appears effective in reducing coal production shifts, although the shifts are greater than that projected under H.R. 3400. On a State-by-State basis, West Virginia almost breaks even with a net lost under H.R. 4404 of 4 million tons. Kentucky, however, does break even.

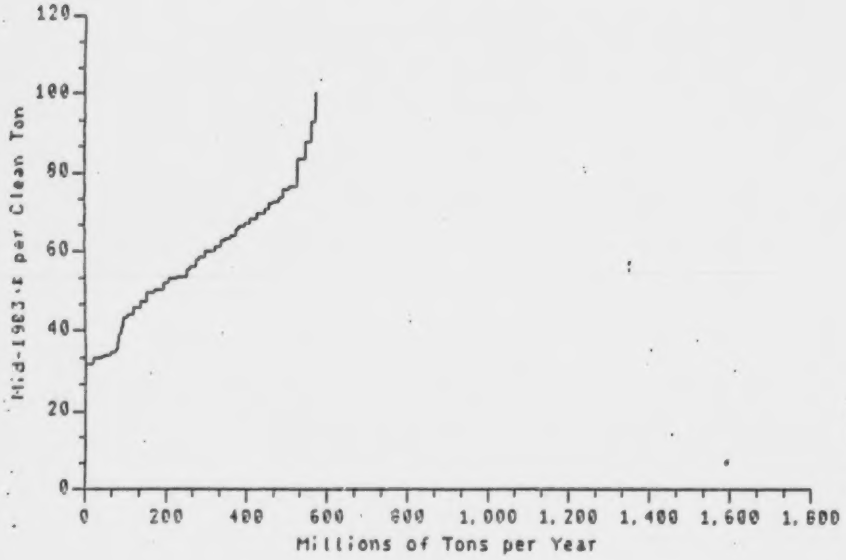
Price Impact

Because all of the models work on a "least-cost" (i.e. polluters will chose the least expensive control method) methodology, price is the privotal component in determining the mix of control methods chosen by each model. For low-sulfur coal, two aspects of price are important: (1) the absolute price increase due to legislation, and (2) the resulting price differential between low and high sulfur coals. The first component is important because of its potential impact on other low-sulfur coal markets (exports and metallurgical demand) and the possibility of foreign low-sulfur coal being imported into the U.S. or western coal being shipped into eastern markets to meet the increased demand. The second is important for determining the degree to which low-sulfur coal would be preferred over high-sulfur coal with FGD, in the absence of rate increases by railroads.

ICF. In October 1983, ICF Incorporated made some modifications in its coal supply curves in response to refined data regarding reserve bases and mining technology. With the exception of southern West Virginia compliance coal, these changes made ICF compliance and low-medium sulfur Appalachian coal supply curves more elastic than the previous 1981 curves. Figures 6 and 7 are "representative" 1983 supply curves for the Appalachian coal regions for low sulfur reserves. 21/

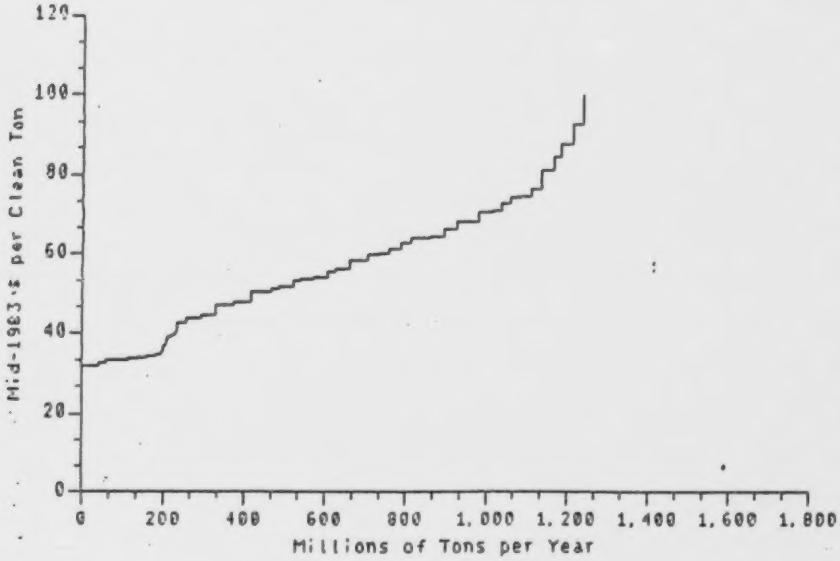
21/ It is emphasized that these curves are an aggregation of a broad range of different coal types from a number of different regions, and, therefore, should be viewed as "representative". ICF Incorporated. Representative Supply Curves for Different Coal Producing Regions in the U.S. Prepared for Gene Trisko, Attorney, October 21, 1983.

Figure 6: Coal Supply Curves for Central Appalachia Compliance Reserves



Source: ICF Incorporated, 1983

Figure 7: Coal Supply Curves for Central Appalachia Compliance and Low-Medium Sulfur Reserves



Source: ICF Incorporated, 1983

As noted earlier, most of ICF's projected increase in central Appalachian coal production is to occur in compliance coal. Assuming the 50 million ton increase from projected levels, the supply curves suggest that compliance coal costs would increase roughly $13 a ton (mid-1983 dollars). In contrast, low-medium coal prices would not be greatly affected by the program because of slack demand. As discussed later, a $13 a ton increase in compliance coal costs could have a significant impact on the ability of coal producers to export some of their production.

Table 14 shows the delivered price differentials between coal types and sulfur contents for ICF's 13.1 million ton scenario done for the EEI. It should be noted that this analysis was done with the 1981 supply curves and assumptions about rail rates. The maximum price differential indicated by the table is in western Kentucky where the shift between high sulfur (5 lb. per million Btus) and compliance coal was about $20 a ton. However, note that this is only one analysis: different assumptions would result in different price differentials.

DRI. Table 15 shows the marginal mine-mouth price (1982 dollars) for central Appalachian coal as estimated by DRI. Unfortunately, DRI's sulfur categories are based on sulfur percent, not on lbs. of SO2 per million Btus. As noted earlier, compliance coal by sulfur percentage results in a sliding scale according to Btu content. For eastern, high Btu, low-sulfur coal, a 1.2 lb. per million Btus coal would contain about .7 to .8 percent sulfur. Hence, DRI's low-medium category (.65 to 1.04 percent) probably more accurately reflects

Table 14

DELIVERED BITUMINOUS COAL PRICES IN 1990[a]
FOR SELECTED UTILITY DEMAND REGIONS
(early 1982 $/$10^6$ Btu)

Region	Coal-Type and Sulfur Content (Washed lbs. $SO_2/10^6$ Btu)			
	1.20	1.67	3.33	5.00
New England				
Massachusetts/Connecticut/Rhode Island	--	2.56	--	2.20
Middle Atlantic				
Pennsylvania, East/New Jersey/ New York, Downstate	2.51	--	2.01	1.91
South Atlantic				
Northern Florida	2.82	2.72	2.30	2.16
East North Central				
Northern Ohio	2.50	--	1.91	1.75
Illinois[b]	2.29	2.28	1.96	1.56
East South Central				
Kentucky (West)	2.43	2.36	1.95	1.57
West Bank Mississippi				
Missouri[c]	2.19	--	1.80	1.50

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[a] Costs are in early 1982 dollars.

[b] Illinois also consumes subbituminous coals with delivered coal prices as follows:

Coal-Type	$1982/$10^6$ Btu
1.20	$1.92
1.67	1.81
3.33	1.26

[c] Missouri also consumes subbituminous coals with delivered price of $1.75 ($1982/10^6 Btu) for a 1.67 lbs. $SO_2/10^6$ Btu coal.

Source: ICF Incorporated, 1982

Table 15: DRI's Price Impact on Central Appalachian Coal
(1982 dollars)

Sulfur Content (percent)	Base Case ($/ton)	Change in $/Ton	
		S. 768	H.R. 3400
0.00-0.64 (compliance)	69.18	0.17	0.17
0.65-1.04 (compliance and low-medium)	58.21	6.54	3.73
1.05-1.84 (medium)	53.18	0.71	(0.86)

Source: DRI Incorporated. Assessing the Impacts of Proposed Acid Rain Legislation. December 14, 1983.

increases in compliance coal than the lower sulfur catagory. This low-medium coal category shows a increase of $6.54 a ton (1982 dollars) projected to result from the 8 million ton reduction embodied in S. 768.

Price differentials between compliance and medium quality coals are not projected to change much from the $16.00 a ton level set in the base case. However, differentials between medium and compliance/low-medium are projected to increase to about $11.50 a ton under S. 768. As indicated in the table, H.R. 3400 significantly reduces the increase in low-medium coal prices with its mandated technology approach to part of the reduction requirement.

OTA. As discussed earlier, OTA does not project the future dynamics of the coal market, but rather relies on historial data to estimate future price. Table 16 provides a selection of the alternative coals available to specific plants in different States. (A complete list is provided in Appendix C). These coals are compared with the base year (1980 coal) and can be blended with or totally replace those coal for specific units. A list of the 1980 coal prices was presented earlier.

Table 16: Data on AIRCOST Alternate Coals

DESTINATION STATE=DELAWARE

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
3	VIRGINIA	0.8	12.8	12374	215.6
5	PENNSYLVANIA	1.4	13.0	12463	180.0

DESTINATION STATE=DISTRICT OF COLUMBIA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
3	VIRGINIA	0.8	12.8	12374	203.7
8	OHIO	2.3	11.9	11641	201.5

DESTINATION STATE=FLORIDA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	ALABAMA	0.7	11.8	12331	234.8
3	VIRGINIA	0.8	12.8	12374	183.9

DESTINATION STATE=GEORGIA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	ALABAMA	0.7	11.8	12331	184.4
4	TENNESSEE	1.1	11.4	12334	178.5
8	INDIANA	2.1	10.9	10762	139.1
9	INDIANA	3.2	10.6	10896	137.9

DESTINATION STATE=IDAHO

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	128.5
3	WYOMING	0.6	7.8	8962	127.0

DESTINATION STATE=ILLINOIS

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	226.1
2	COLORADO	0.5	8.9	10759	225.1
3	VIRGINIA	0.8	12.8	12374	203.7
5	PENNSYLVANIA	1.4	13.0	12463	179.0
6	OKLAHOMA	1.8	10.6	12424	159.6
8	INDIANA	2.1	10.9	10762	152.8

Table 16: Data on AIRCOST Alternate Coals (continued)

DESTINATION STATE-ILLINOIS

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
9	INDIANA	3.2	10.6	10896	131.6

DESTINATION STATE-INDIANA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	256.4
2	MONTANA	0.4	4.2	9521	227.8
3	VIRGINIA	0.8	12.8	12374	200.0
4	KENTUCKY	1.0	11.8	12016	144.8
5	KENTUCKY	1.3	11.8	12104	144.0
8	INDIANA	2.1	10.9	10762	126.9
9	INDIANA	3.2	10.6	10896	125.7

DESTINATION STATE=IOWA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	266.9
2	IOWA	0.4	11.8	10105	140.5
4	NORTH DAKOTA	0.6	9.8	6610	105.3

DESTINATION STATE=KANSAS

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	178.4
2	WYOMING	0.4	6.5	8734	131.2
3	WYOMING	0.6	7.8	8962	129.7
8	MISSOURI	2.2	7.0	12498	110.6

DESTINATION STATE=KENTUCKY

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	205.2
3	WYOMING	0.6	7.8	8962	203.7
4	KENTUCKY	1.0	11.8	12016	172.3
5	PENNSYLVANIA	1.4	13.0	12463	170.8
8	INDIANA	2.1	10.9	10762	132.7
9	INDIANA	3.2	10.6	10896	131.5

Source: E.H. Pechan and Associates

ANALYSIS OF CRITICAL ISSUES

Coal Production

The numerous studies reviewed in the previous section indicate a range of increased Appalachian low-sulfur coal production of between 35 to 50 million tons. The range generally results from the models' differing assumptions regarding western coal penetration into the Midwest. ICF assumes vitually no penetration, while DRI assumes fairly free substitution of Powder River coal for current high-sulfur bituminous coal. OTA is in the middle assuming some blending of coals within specific Btu parameters.

Historical evidence regarding midwestern utilities meeting SIP requirements suggests that western coal is a viable reduction alternative. As shown earlier, many units in Illinois have switched to low-sulfur western coal but Eastern low-sulfur coal has not penetrated very much into the area. Western penetration appears to extend as far as western Indiana and Michigan. The current situation does not suggests that this penetration can move much farther East unless transportation or tax rates are lowered. However, it does suggest that ICF's assumption that midwestern utilities are unwilling or unable to switch to lower-rank western coals may be too strigent, and, at least to some degree, the shift suggested by DRI and OTA may occur. The result would be less growth in eastern Appalachian coal production, and fewer jobs created.

The reaction of other low-sulfur appalachian coal markets in response to higher prices may have a greater impact on absolute increases in low-sulfur coal production than western penetration. Currently, coal producers mining low-sulfur coal for exports are not receiving what would be considered a fair rate of return. Indeed, the current and projected competition for exports indicates that growth in exports may be less than expected a years ago. Hence, if these coal producers are permitted to receive even a small increase in price, they would have a very strong incentive to switch their production from the export market to the domestic steam market. The extent of this shift would depend on how many exporters have compliance quality coal and how much of that coal is either medium or high volatile, i.e. suitable for use in a utility boiler. Theoretically, if sufficient boiler coal currently or projected to be dedicated to the export market shifted to the domestic steam market, the net 1993 coal production in central Appalachia could be no greater than that projected under a no acid rain program scenario. This assumes producers would not be willing to accept the lower export price and to continue exporting in addition to meeting the increased domestic demand.

The railroads would have a major role in determining any increase in central Applachian coal production. They could decide to lower their rates for coal headed for export in order to prevent a significant shift in export demand away from the eastern U.S. supply. However, they have not done so and the U.S. remains the world supplier of highest price. The potential shift or increase in coal production may put some strain on the coal transportation network, and present the possibility of rising prices by constraining supply. Also, regardless of system overload, shifting demand may create opportunities for some transporters to extract additional economic rents by capitalizing on the captivity of some shippers.

Such a modest increase in central Appalachian coal production (equivalent to that of one or two large western mines) would probably represent no great strain on current Eastern low-sulfur coal reserves. Indeed, if acid rain legislation results in merely a shift in coal demand from the export market to the domestic steam market, then the strain would be no greater than that projected without acid rain controls. Also, if the price of low-sulfur coal at the mine rises, then the demonstrated reserve base will also increase.

Any increase or shift in central Appalachian coal production from acid rain legislation may come from middle-volatile coal producers whose coal can be used for either steam or coking. These producers have been hurt very badly by the drop in exports and may have the excess capacity available to quickly meet any increased demand for low-sulfur coal under an acid rain program. Also, these producers have been hurt by forced reductions in price required by exporters in recent months and therefore would have the incentive to shift their production from export to domestic steam markets.

This situation suggests that there would not be a massive increase in eastern Appalachian low-sulfur coal production resulting from acid rain control. The low end of the projected increases may be the high end given the fluctuations in the export market. If, in response to higher prices from acid rain legislation, overseas buyers decide to limit their purchases of U.S. coal to that considered absolutely necessary for security purposes, then no increased production may occur.

If a modest increase in central appalachian coal production should occur, then West Virginia would probably break even or even have a gain in overall coal production resulting from acid rain legislation. However, for Kentucky, the significant losses projected for the State's western high-sulfur coal producing region combined with a projected modest increase in eastern low-sulfur coal production would probably result in a net loss. The extent of this loss would depend on western coal penetration, which may be significant.

If low-sulfur coal producers shift their production from export to domestic steam markets, then both States would lose significant coal production due to acid rain legislation.

Costs

The numerous studies reviewed in the previous section indicate a range of increased costs for Appalachia low-sulfur coal of between zero and $13 a ton. The range is generally produced by the inherent nature of the models' methodology and the amount of fuel switching they project. OTA uses historial data as a basis for analysis and therefore assumes no increase in low-sulfur coal prices. ICF, which projects the greatest amount of fuel-switching, projects the greatest increase in costs--$13 a ton (1983 dollars). Finally, DRI, which projects less fuel-switching, projects a "medium" price rise of $6.54 a ton (1982 dollars).

Because of the potential export losses due to acid rain legislation and western coal penetration, the lower half of the cost estimates are probably more likely to occur under acid rain legislation. As suggested in the previous section, acid rain legislation could result in a significant shift in production between export and domestic steam markets. Given current market conditions, the mine-mouth price of low-sulfur coal would not have to increase much to provide an significant incentive to begin the shift.

However, this possibility of lower mine-mouth coal prices does not necessary mean that fuel-switching would increase. The choice of fuel-switching versus an alternative is determined on the basis of delivered coal prices and other factors, not mine-mouth costs. For example, OTA, which assumes no increase in low-sulfur coal prices, projects considerably less fuel-switching than ICF which projects the highest increases in low-sulfur coal prices. Other variables, such as high-sulfur coal prices, FGD costs, and perhaps most important, projected transportation costs, have a great influence on the final cost of the low-sulfur coal alternative.

The amount of fuel-switching which would occur under acid rain legislation is determined primarily by the amount of economic rent created by the increased demand for compliance coal that is allowed to be accrued by utility consumers, as opposed to other parts of the economic chain. This would also determine the ultimate cost of such a program to consumers and whether a "least cost" strategy as designed by the models would indeed be least-cost to electricity consumers.

The railroads, State governments, and the coal industry might be in positions to capture the rent. The railroads' general market position is enhanced by two factors. First, in many cases, the demand for low-sulfur coal may be inelastic. As shown by the data collected by OTA, sulfur content is not a good indicator of price. Btu content, ash (and its fusion temperature), and metal composition of a particular coal have a significant impact on the appropriateness of that coal to a specific boiler. These variables tend to work to the advantage of Appalachian coal which is generally low ash and high Btu. Also, inelasticity may result from the inability of particular boilers to employ other alternatives, such as FGD, because of site-specific constraints and the age of the boiler. Finally, there is institutional interia to FGD as utilities have traditionally perferred to fuel-switch rather than deal with the operational aspects of FGD.

Secondly, unlike the western coal industry, transportation costs are less of a cost component in the overall cost of eastern coal, as the coal is high cost and transportation distances less than in the West. As shown earlier in the DOE report, eastern rail rates could increase greatly before a significant reduction would occur in central appalachian coal production.

Eastern State governments, parficularly West Virginia and Kentucky, would appear more constrained in accruing potential rents (through severance taxes) than the transportation sector. Both West Virginia and Kentucky have sizeable high-sulfur coal industries in addition to their low-sulfur coal industry. Hence, any increase in a State severance tax to collect rents, as is done in Montana, would have an adverse affect on their high-sulfur coal industry.

A third possible collector of rent could be the eastern coal industry. However, given the large number of mines in the East and the excess capacity, individual operators would appear to be price-takers, not price setters. If some consolidation of these companies (or a complete shake-out of small operations) were to occur in the next ten years, then the industry's ability to collect some rent would be enhanced.

The final possible collector of rent would be electricity consumers in the form of lower electricity bills. "Least-cost" methodology assumes that indeed these consumers will collect the rents. However, they are the last link in the chain from extraction to conversion and therefore may only receive that which is necessary to prevent the utility from choosing an alternative control strategy.

If price is set by the availability of alternatives, four alternatives to using eastern low-sulfur coal stand out. First, there is FGD. FGD permits utilities to use high-sulfur coal instead of low-sulfur coal to meet reduction requirements. There is a slump at the current time in the FGD market, resulting in stable or even declining prices for this technological alternative. Also, high-sulfur coal companies could lower their prices (if feasible) in an attempt to make the high-sulfur coal-FGD alternative more attractive. However, FGD requires adequate space at a plant for installation and operations, including sludge disposal. Also, because FGD requires a major capital investment, the expected life of the boiler being retrofitted must be sufficient to justify the expenditure. Finally, the economics of FGD are significantly affected by the size of the boiler being fitted.

A second alternative is western coal. Western coal is cheaper to mine and the railroads are already collecting significant rents on its transportation. However, this alternative is primarily restricted to parts of the Midwest. Western coal, as low-sulfur coal, would carry a premium which would be collected by the western coal industry, State governments, or the railroads. Hence, the extent to which the coal can move further east would depend on what these groups would consider an acceptable price for the coal.

A third alternative is imported coal. Some States, such as Florida, already import a little low-sulfur coal to meet requirements. As other countries, such as Colombia, develop their export capacity, the eastern U.S. steam coal market would be an attractive target for them. Such coal would not be dependent on domestic transportation to reach a port. However, such an alternative is probably restricted to the coastal area as any penetration inland would require use of domestic transportation.

A final alternative discussed here would be for development of new technology to achieve the necessary reduction at less cost than FGD. Such development would reduce the cost of an alternative to low-sulfur coal, and therefore reduce or eliminate the premium created by acid rain legislation. However, whether such technologies would be developed in time and whether utilities would be willing to accept the risk involved is unknown.

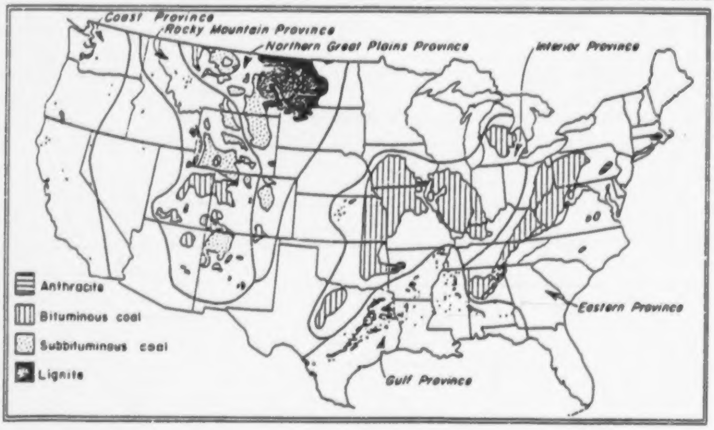
This discussion suggests that the actual cost of acid rain legislation to electricity consumers may be greater than that projected by the models as economic groups involved in the low-sulfur coal industry attempt to profit from its status as the least expensive alternative. Theoretically, the costs could rise to that of the next least-cost alternative to low-sulfur coal. In many cases, that next least-cost alternative would be FGD. This suggests the possibility that the cost differential between "least-cost" strategies and partially or fully technology-mandated strategies which attempt to protect some high-sulfur coal industry jobs may be significantly overstated by the models. This potential overestimate of "savings" from fuel-switching is important, as the "savings" resulting from a "least-cost" strategy are given as a primary reason for accepting the significant economic dislocation in high-sulfur coal regions resulting from a SO2 reduction program that does not protect the high-sulfur coal industry.

APPENDIX A: BACKGROUND ON U.S. LOW-SULFUR COAL RESERVES AND RESOURCES

LOW SULFUR COAL-PRODUCING PROVINCES

Coal has been discovered in several parts of the United States, as shown in Figure 8. However, about 90 percent of the country's coal resources occur in four U.S. Geological Survey provinces: the Eastern (Appalachian), Interior, Northern Great Plains, and Rocky Mountain. The interior province has little low-sulfur coal (i.e., 1.2 lb. of SO2 per mmbtus or less) and therefore is not be discussed here. 22/

Figure 8: Distribution of United States Coal Resources


Coast Province
Rocky Mountain Province
Northern Great Plains Province
Interior Province
Eastern Province
Gulf Province
Anthracite
Bituminous coal
Subbituminous coal
Lignite

Source: U.S., Department of the Interior, Bureau of Land Management. *Draft Environmental Impact Statement: Proposed Federal Coal Leasing Program*, 2 vols. Washington: Government Printing Office. 1974.

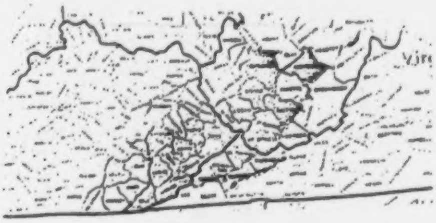
22/ For a discussion of the Eastern Interior basin and acid rain legislation, see Parker, Larry. Mitigating Acid Rain: Implications for High-Sulfur Coal Regions. Unnumbered CRS Report, May 16, 1983.

1. Appalachian Province

The Appalachian coal region extends about 800 miles from northern Pennsylvania to western Alabama, including portions of Pennsylvania, Maryland, Virginia, West Virginia, Ohio, Tennessee, Kentucky, and Alabama. The low-sulfur coal areas of this formation are generally located in central Appalachia, particularly southern West Virginia and eastern Kentucky, although some low-sulfur coal also exists in Virginia and Alabama. This low-sulfur coal represents about 7 percent of the nation's demonstrated reserve base.

As shown in figure 9, coal production in central Appalachia is located in a belt bounded in the north by Kanawha and Nicholas counties in West Virginia and by the Tennessee border on the south. However, not all of the coal mined in this area is of compliance quality, and much of the production is used for blending to make metallurgical coke for ironmaking. This is particularly true for coal mined in the southeastern part of West Virginia.

Figure 9: Coal-Producing Counties in Central Appalachia

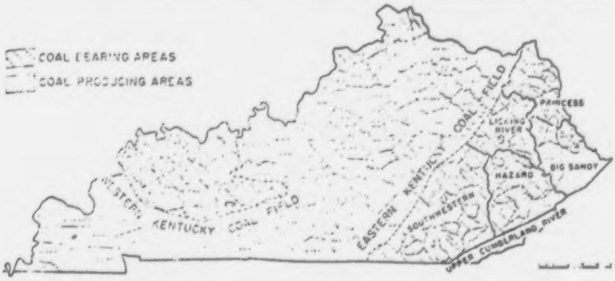


Source: Keystone Industry Manual, 1981.

In Kentucky, the major seams that have coal with a .7 percent sulfur content or less include Elkhorn nos. 1, 2, 3; Hazard nos. 4, 5, 5A, 8; High Splint, Leatherwood, Lower Elkhord, No. 1 1/2, No. 5 and Upper Mason. These seams are generally located in three coal districts in eastern Kentucky: Big Sandy, Hazard, and Upper Cumberland River (see figure 10). Much of the coal mined in eastern Kentucky is used in electric steam plants.

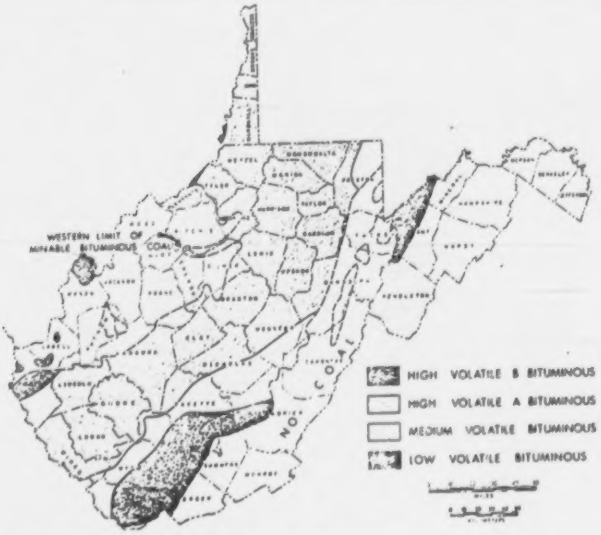
In West Virginia, the low-sulfur coal seams include Alma, Beckley, Chilton, Coalburg, Dorothy, Eagle, Fire Creek, No. 2 Gas, No. 5 Block, Pocahontas nos. 3, 4, 5, 6, 11; Powellton, Sewell, Stockton-Lewiston, Welch, and Winifrede. In particular, Pocahontas no. 3 probably represents the finest low-volatile, low-sulfur, low-ash, high-Btu coking coal available in the world. Low volatile coal mined in southeastern West Virginia (see Figure 11) is primarily used for coke making, and its fine quantity has generally been reflected in a premium price. The coal west of the low volatile deposits has higher volatility and is also used for steam purposes, although some of it swings from steam to metallurgical purposes, depending on market conditions.

Figure 10: Coal Producing Districts in Kentucky


COAL BEARING AREAS
COAL PRODUCING AREAS
WESTERN KENTUCKY COAL FIELD
EASTERN KENTUCKY COAL FIELD
PRINCESS
LICKING RIVER
BIG SANDY
HAZARD
SOUTHWESTERN
UPPER CUMBERLAND RIVER

Source: Keystone Coal Mine Production by Seam, 1976

Figure 11: Rank and Fixed Carbon of West Virginia Coal


WESTERN LIMIT OF MINEABLE BITUMINOUS COAL
NO COAL
HIGH VOLATILE B BITUMINOUS
HIGH VOLATILE A BITUMINOUS
MEDIUM VOLATILE BITUMINOUS
LOW VOLATILE BITUMINOUS

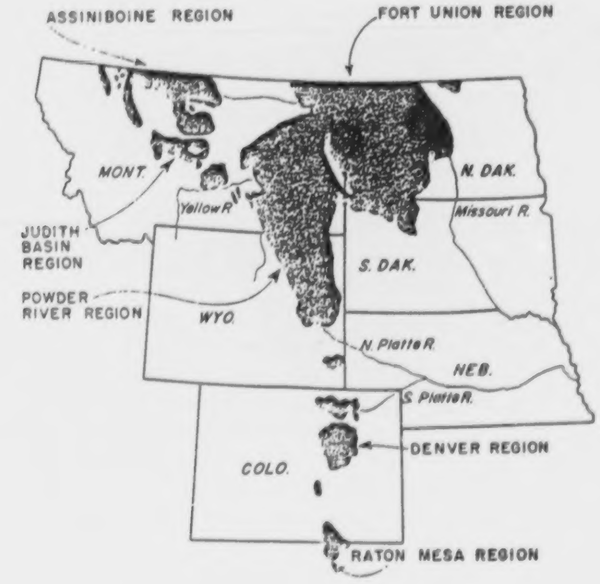
Source: Keystone Industry Manual, 1981.

2. Northern Great Plains Province

As shown in Figure 12, the Northern Great Plains Province covers parts of five States: Montana, North Dakota, South Dakota, Wyoming, and Colorado. The province, which is estimated to contain about 45 percent of nation's coal resources, is divided into 6 districts. The two largest are Fort Union and Powder River. However, these coals are lignite and subbituminous respectively. Higher rank bituminous coal is available closer to the Rocky Mountains, particularly in regions of Colorado.

As indicated in Figure 13, current production in the North Great Plains is located primarily in the Powder River Basin with some lignite production in North Dakota, and bituminous production in lower Colorado and New Mexico.

Figure 12: Distribution of Coal in the Northern Great Plains Province

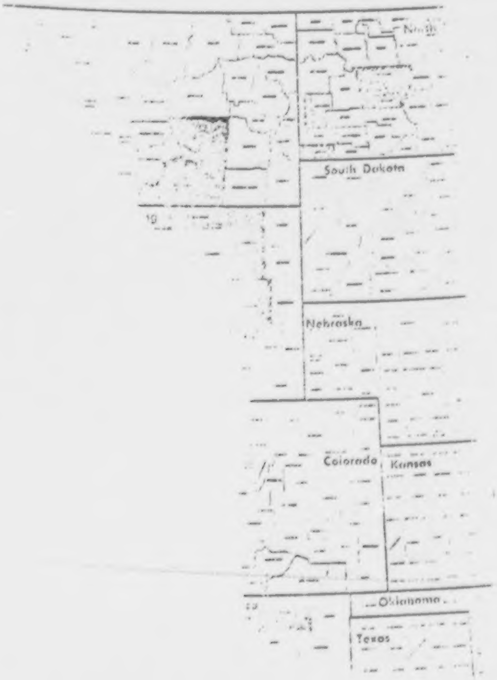

ASSINIBOINE REGION
FORT UNION REGION
MONT.
N. DAK.
Yellow R.
Missouri R.
JUDITH BASIN REGION
S. DAK.
POWDER RIVER REGION
WYO.
N. Platte R.
NEB.
S. Platte R.
DENVER REGION
COLO.
RATON MESA REGION

Source: U.S., Department of the Interior, Bureau of Land Management. Draft Environmental Impact Statement: Proposed Federal Coal Leasing Program. 2 vols. Washington: Government Printing Office. 1974. p. II-132.

The bituminous coal in New Mexico is mined largely by Kaiser Steel for both coke and steam purposes.

The major beds producing subbituminous coal in the Powder River Basin are the Wyodak-Anderson and Anderson-Dietz. Much or the rapid increase in western coal in the last 10 ten years has occured in the Powder River Basin. Under the current Administration, substantial amounts of additional coal from this basin has been leased for future exploitation.

Figure 13: Production of Coal in Northern Great Plains Province

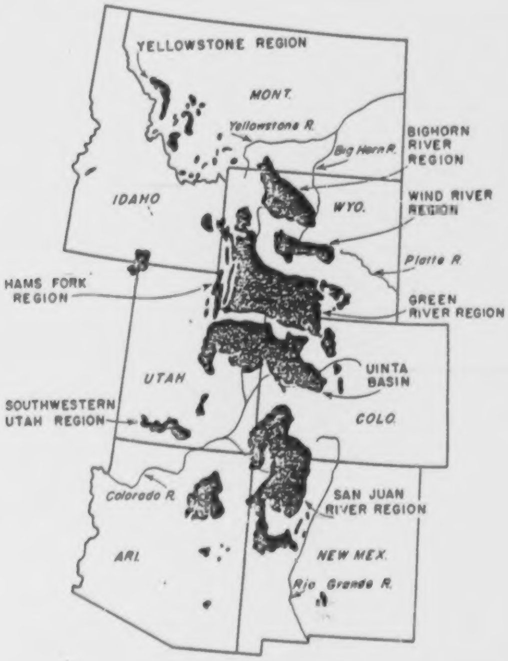

North
South Dakota
Nebraska
Colorado
Kansas
Oklahoma
Texas

Source: Keystone Industry Manual, 1981.

3. Rocky Mountain Province

As shown in figure 14, the Rocky Mountain Province covers parts of seven western States: Montana, Idaho, Wyoming, Utah, Colorado, Arizona, and New Mexico. Divided into eight regions, the three largest are Green River, Uinta Basin and San Juan River. The coals of these three regions are of great interest currently. Moisture content is fairly low and volatility

Figure 14: Distribution of Coal in the Rocky Mountain Province.

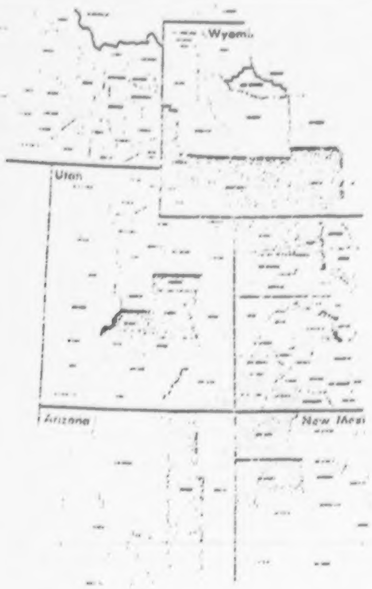

YELLOWSTONE REGION
MONT.
Yellowstone R.
BIGHORN RIVER REGION
Big Horn R.
IDAHO
WYO.
WIND RIVER REGION
Platte R.
HAMS FORK REGION
GREEN RIVER REGION
UINTA BASIN
UTAH
SOUTHWESTERN UTAH REGION
COLO.
Colorado R.
SAN JUAN RIVER REGION
ARI.
NEW MEX.
Rio Grande R.

Source: U.S., Department of the Interior, Bureau of Land Management. *Draft Environmental Impact Statement: Proposed Federal Coal Leasing Program*, 2 vols. Washington: Government Printing Office, 1974.

fairly high. Also, about 90 percent of the identified reserves have a sulfur content of 1 percent or less.

As shown in Figure 15, major production from this province occurs in western Wyoming, Colorado, and New Mexico, and central Utah. Some of the production, particularly in Utah, is used for metallurgical purposes. Some of the major fields in the region include: Book Cliffs, Wasatch Plateau, Rock Springs, Hanna, Adaville, Navajo, and Gallup. Unlike the major subbituminous deposits of the Northern Great Plains provinces, much of

Figure 15: Production of Coal in Rocky Mountain Province.



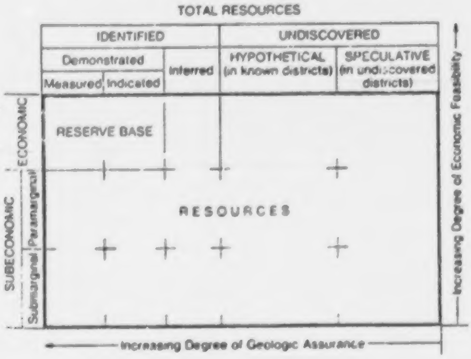
Source: Keystone Industry Manual, 1981.

the coal in the Rocky Mountain province is deep-mined, particularly in Utah and Colorado.

RESOURCES AND RESERVES

In discussing the potential for coal development, a distinction is made between the terms "resources" and "reserves". "Resources" include the total amount of substance potentially available, regardless of the difficulty involved in exploiting it. "Reserve base", however, is a much more limited term involving the actual existence of the resource based on seam thickness and depth and its economic viability. As shown in figure 16, the two criteria of existence

Figure 16: Coal Reserve Classification


TOTAL RESOURCES
IDENTIFIED
UNDISCOVERED
Demonstrated
Measured
Indicated
Inferred
HYPOTHETICAL (in known districts)
SPECULATIVE (in undiscovered districts)
ECONOMIC
SUBECONOMIC
Paramarginal
Submarginal
RESERVE BASE
RESOURCES
Increasing Degree of Economic Feasibility
Increasing Degree of Geologic Assurance

Source: U.S. Geological Survey Bulletin 1412, 1975.

and economics formed a matrix of different reserve base catagories.

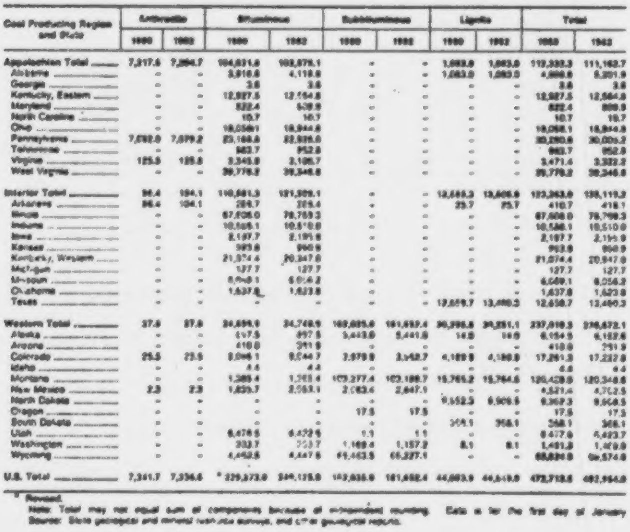
Most analyses of coal markets are based on the demonstrated reserve base or DRB, the two strictest categories of reserves in figure 16. The DRB criteria for existence involves resources which are either measured 23/ or indicated 24/. The economic criterion involves the ability of existing technology to extract the resource at a economic cost. Hence, it assumes some beds are economic even if not currently mined.

23/ Measured Reserve is the tonnage of coal in the ground based on assured coal-bed correlations and on closely spaced observations about one-half mile apart. Computed tonnage judged to be accurate within 20 percent of the true tonnage.

24/ Indicated Reserve is the tonnage of coal in the ground based partly on specific observations and partly on reasonable geologic projection. The points of observations and measurement are about 1 mile apart but may be 1 and 1/2 miles apart for beds of known continuity.

The results of these observations and judgments are shown in tables 17 and 18 for 1982 DOE DRB estimates. The 472 billion ton reserve base is about 10 percent above the 1974 estimate of 432 billion tons. Montana, Illinois, and Wyoming have the largest reserve base, in terms of tonnage, by a considerable margin. However, if the heat content of the coal is taken into account, the reserve base of Montana and Wyoming shrink considerably.

Table 17: Demonstrated Reserve Base of Coal by Rank 1982
(million short tons)



Coal Producing Region and State	Anthracite		Bituminous		Subbituminous		Lignite		Total	
	1980	1982	1980	1982	1980	1982	1980	1982	1980	1982
Appalachian Total	7,217.5	7,204.7	104,031.6	102,875.1	-	-	1,083.0	1,083.0	112,332.3	111,162.7
Alabama	-	-	3,916.6	4,118.8	-	-	1,083.0	1,083.0	4,999.6	5,201.8
Georgia	-	-	3.6	3.6	-	-	-	-	3.6	3.6
Kentucky, Eastern	-	-	12,927.5	12,564.8	-	-	-	-	12,927.5	12,564.8
Maryland	-	-	822.4	809.9	-	-	-	-	822.4	809.9
North Carolina	-	-	10.7	10.7	-	-	-	-	10.7	10.7
Ohio	-	-	18,058.1	18,944.8	-	-	-	-	18,058.1	18,944.8
Pennsylvania	7,092.0	7,079.2	23,198.6	22,926.0	-	-	-	-	30,290.6	30,005.2
Tennessee	-	-	983.7	952.8	-	-	-	-	983.7	952.8
Virginia	125.5	125.5	3,345.9	3,196.7	-	-	-	-	3,471.4	3,322.2
West Virginia	-	-	39,778.2	39,346.8	-	-	-	-	39,778.2	39,346.8
Interior Total	96.4	104.1	110,881.3	121,509.1	-	-	12,685.2	13,505.9	123,263.0	135,119.2
Arkansas	96.4	104.1	288.7	289.4	-	-	25.7	25.7	410.7	419.1
Illinois	-	-	67,608.0	78,769.3	-	-	-	-	67,608.0	78,769.3
Indiana	-	-	10,586.1	10,510.0	-	-	-	-	10,586.1	10,510.0
Iowa	-	-	2,197.7	2,195.9	-	-	-	-	2,197.7	2,195.9
Kansas	-	-	993.8	990.9	-	-	-	-	993.8	990.9
Kentucky, Western	-	-	21,074.4	20,947.0	-	-	-	-	21,074.4	20,947.0
Michigan	-	-	127.7	127.7	-	-	-	-	127.7	127.7
Missouri	-	-	6,069.1	6,056.2	-	-	-	-	6,069.1	6,056.2
Oklahoma	-	-	1,637.8	1,623.8	-	-	-	-	1,637.8	1,623.8
Texas	-	-	-	-	-	-	12,659.5	13,480.2	12,659.5	13,480.2
Western Total	37.6	37.6	24,699.0	24,748.9	163,835.6	161,652.4	30,398.6	30,351.1	237,910.3	236,872.1
Alaska	-	-	697.5	697.5	5,443.0	5,441.0	14.0	14.0	6,154.5	6,152.5
Arizona	-	-	410.0	351.9	-	-	-	-	410.0	351.9
Colorado	25.5	25.5	9,046.1	9,044.7	3,979.9	3,952.7	4,189.9	4,189.9	17,241.3	17,212.8
Idaho	-	-	4.4	4.4	-	-	-	-	4.4	4.4
Montana	-	-	1,385.4	1,385.4	103,277.4	102,189.7	15,765.2	15,764.6	120,428.0	120,340.6
New Mexico	2.3	2.3	1,835.7	2,083.1	2,683.6	2,647.1	-	-	4,521.6	4,732.5
North Dakota	-	-	-	-	-	-	9,552.3	9,908.5	9,552.3	9,908.5
Oregon	-	-	-	-	17.5	17.5	-	-	17.5	17.5
South Dakota	-	-	-	-	-	-	368.1	368.1	368.1	368.1
Utah	-	-	6,476.5	6,422.6	1.1	1.1	-	-	6,477.6	6,423.7
Washington	-	-	303.7	303.7	1,169.4	1,157.2	8.1	8.1	1,481.2	1,469.0
Wyoming	-	-	4,452.5	4,447.6	65,463.5	65,227.1	-	-	69,916.0	69,674.8
U.S. Total	7,341.7	7,336.6	a 239,273.0	249,135.0	163,835.6	161,652.4	44,093.9	44,848.0	472,719.5	482,964.0

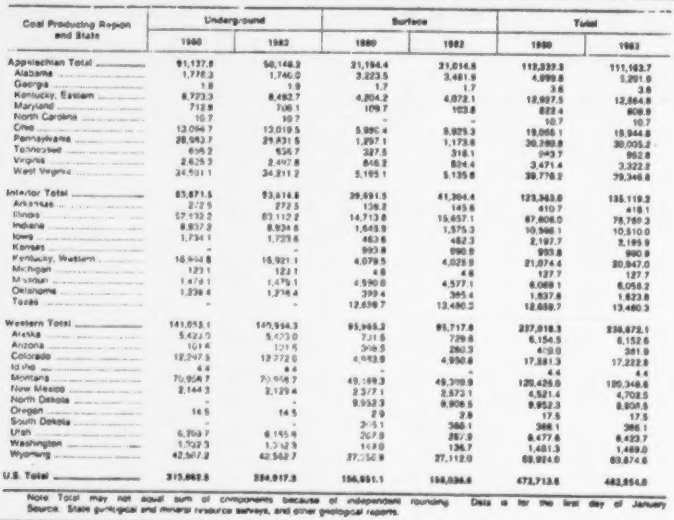
a Revised.

Note: Total may not equal sum of components because of independent rounding. Data is for the first day of January

Source: State geological and mineral resource surveys, and other geological reports.

Source: Department of Energy. 1982 Coal Production Annual.

Table 18: Demonstrated Reserve Base of Coal by Potential Method of Mining
(million short tons)



Coal Producing Region and State	Underground		Surface		Total	
	1980	1982	1980	1982	1980	1982
Appalachian Total	91,137.9	90,148.2	21,194.4	21,014.5	112,332.3	111,162.7
Alabama	1,776.3	1,740.0	3,223.5	3,461.9	4,999.8	5,201.9
Georgia	1.9	1.9	1.7	1.7	3.6	3.6
Kentucky, Eastern	8,723.3	8,492.7	4,204.2	4,072.1	12,927.5	12,564.8
Maryland	712.8	706.1	109.7	103.8	822.4	809.9
North Carolina	10.7	10.7	-	-	10.7	10.7
Ohio	13,066.7	13,019.5	5,990.4	5,925.3	19,056.1	18,944.8
Pennsylvania	28,993.7	28,831.5	1,297.1	1,173.6	30,290.8	30,005.2
Tennessee	656.2	634.7	327.5	318.1	983.7	952.8
Virginia	2,625.3	2,497.8	846.2	824.4	3,471.4	3,322.2
West Virginia	34,581.1	34,211.2	5,195.1	5,135.6	39,776.2	39,346.8
Interior Total	83,871.5	93,814.8	39,491.5	41,304.4	123,363.0	135,119.2
Arkansas	272.5	272.5	138.2	145.6	410.7	418.1
Illinois	52,892.2	63,112.2	14,713.8	15,657.1	67,606.0	78,769.3
Indiana	8,937.2	8,934.6	1,648.9	1,575.3	10,586.1	10,510.0
Iowa	1,734.1	1,733.6	463.6	462.3	2,197.7	2,195.9
Kansas	-	-	993.8	990.9	993.8	990.9
Kentucky, Western	16,994.9	16,921.1	4,079.5	4,025.9	21,074.4	20,947.0
Michigan	123.1	123.1	4.6	4.6	127.7	127.7
Missouri	1,479.1	1,479.1	4,590.0	4,577.1	6,069.1	6,056.2
Oklahoma	1,238.4	1,238.4	399.4	385.4	1,637.8	1,623.8
Texas	-	-	12,659.7	13,480.3	12,659.7	13,480.3
Western Total	141,053.1	140,954.3	95,965.2	95,717.8	237,018.3	236,672.1
Alaska	5,423.0	5,423.0	731.5	729.6	6,154.5	6,152.6
Arizona	101.5	101.5	308.5	280.3	410.0	381.8
Colorado	12,297.5	12,272.0	4,983.8	4,950.8	17,281.3	17,222.8
Idaho	4.4	4.4	-	-	4.4	4.4
Montana	70,958.7	70,958.7	49,469.3	49,389.9	120,428.0	120,348.6
New Mexico	2,144.3	2,129.4	2,377.1	2,573.1	4,521.4	4,702.5
North Dakota	-	-	9,952.3	9,908.5	9,952.3	9,908.5
Oregon	14.5	14.5	2.9	2.9	17.5	17.5
South Dakota	-	-	366.1	366.1	366.1	366.1
Utah	6,209.7	6,155.8	267.9	267.9	6,477.6	6,423.7
Washington	1,332.3	1,332.3	149.0	136.7	1,481.3	1,469.0
Wyoming	42,567.2	42,562.7	27,356.9	27,112.0	69,924.0	69,674.6
U.S. Total	315,862.5	324,917.3	156,851.1	158,036.6	472,713.6	482,954.0

Note: Total may not equal sum of components because of independent rounding. Data is for the first day of January.
Source: State geological and mineral resource surveys, and other geological reports.

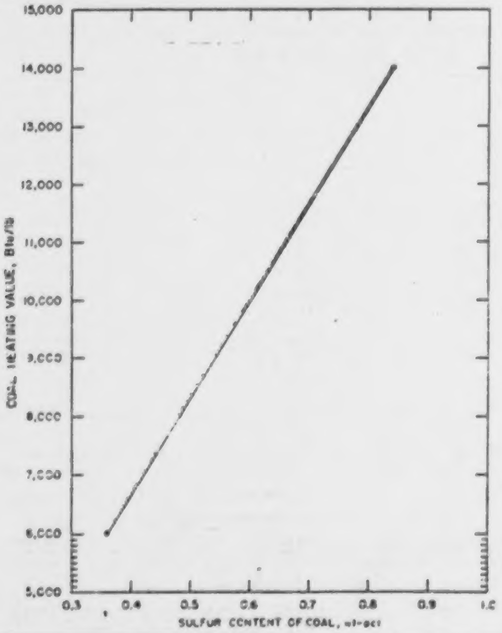
Source: Department of Energy. 1982 Coal Production Annual.

It is important to note that the reserve base does not represent the actual amount of coal that would be recovered under existing technology. The actual recovery factor of the reserve base is currently estimated at roughly 50 percent. Depending on site-specific characteristics of the particular coal seam or the technology used to develop the seam, the recovery factor could range anywhere from 30 to 90 percent of the estimated reserve base.

LOW SULFUR COAL RESERVES

Over the years, the term "low-sulfur" coal has taken on several different meanings. For many years, any coal under 1.5 percent sulfur was considered low-sulfur for steam purposes. During the early 1970s, government documents generally classified coal having less than 1 percent sulfur as "low-sulfur". Coking coals with less than 1 percent sulfur are considered premium coals for metallurgical purposes. With the passage of the Clean Air Act in 1970 and New Source Performance Standards for utility plants, coal emitting 1.2 lb. per million Btus became low-sulfur or compliance coal. This 1.2 lb. per million Btus standard is also referenced in many of the proposed acid rain bills, and hence is the definition used in this report. As shown in Figure 17, such a standard requires lower Btu coals (subbitiminous, lignites, bitiminous C) to have a lower sulfur percentage to meet the standard than higher rank bitiminous coals.

Figure 17: Maximum Permissible Sulfur Content versus Btu Content for meeting 1.2 lb. per mmBtus Standard



Source: Department of Interior

The Department of Energy no longer estimates the DRB according to sulfur content. The last comprehensive report by the government was done in 1974 by the Bureau of Mines. However, a recent DOE analysis of proposed changes to the Clean Air Act did present estimates of 1980 low-sulfur coal reserves. They are presented in table 19.

E.H. Pechan and Associates have also attempted to estimate the country's coal reserve base according to sulfur content. Using the 1980 DRB as a baseline, they prepared the data presented in table 20. As indicated, the two studies differ significantly on the amount of low-sulfur coal available, particularly in eastern States. However, both agree that Eastern reserves are limited primarily to eastern Kentucky and southern West Virginia and, to a lesser extent, Alabama and Virginia.

Table 19: Demonstrated Reserve Base of Low-Sulfur Coal for Selected States[a]
(millions short tons)

State	Low-Sulfur DRB	Total DRB	Percentage of Low-Sulfur to DRB
Penn.	426	30,281	1
W. Va.	12,806	39,776	32
Va.	2,254	3,471	65
Kentucky	5,321	34,002	16
Wyoming	36,147	69,924	52
Colorado	8,864	17,281	51
Montana	118,315	120,428	98
Utah	3,193	6,478	49
N. Mexico	1,822	4,521	40

[a] States in the contiguous United States that have more than 2,000 million tons of coal, including low-sulfur coal, in the DRB.

Sources: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Documentation of the Reserve-Related Data Inputs to the Resource Allocation and Mine-Costing Model, DOE/NBB-0026 (Washington, D.C., September 1982); and Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Demonstrated Reserve Base of Coal in the United States on January 1, 1980, DOE/EIA-0280 (80) (Washington, D.C., May 1982).

Table 20: Demonstrated Reserve Base by Sulfur Category
(millions of tons)

STATE	0-.8	.9-1.2	1.3-2.0	> 2.0	TOTAL
ALABAMA	3	1,287	2,084	1,625	5,000
ALASKA	1,009	73	4,062	1,011	6,154
ARIZONA	0	0	385	25	410
ARKANSAS	0	11	282	117	411
COLORADO	8,313	2,358	5,386	1,225	17,281
GEORGIA	0	0	4	0	4
IDAHO	3	1	0	0	4
ILLINOIS	0	0	4,204	63,402	67,606
INDIANA	0	215	2,283	8,088	10,586
IOWA	0	0	0	2,198	2,198
KANSAS	0	0	0	994	994
KENTUCKY	0	10,286	5,432	18,283	34,002
MARYLAND	0	1	299	522	822
MICHIGAN	0	0	0	128	128
MISSOURI	0	0	0	6,069	6,069
MONTANA	84,218	32,775	1,411	2,025	120,428
NEW MEXICO	1,272	506	2,696	48	4,521
NORTH CAROLINA	0	0	11	0	11
NORTH DAKOTA	563	165	4,860	4,364	9,952
OHIO	0	0	0	19,056	19,056
OKLAHOMA	8	747	305	578	1,638
OREGON	12	0	6	0	17
PENNSYLVANIA	16	561	2,608	27,095	30,281
SOUTH DAKOTA	0	0	267	99	366
TENNESSEE	0	183	291	509	984
TEXAS	0	0	0	12,660	12,660
UTAH	398	4,716	158	1,206	6,478
VIRGINIA	705	1,466	1,043	258	3,471
WASHINGTON	790	15	542	134	1,481
WEST VIRGINIA	3,421	14,680	5,657	16,018	39,776
WYOMING	32,937	9,502	24,825	2,659	69,924
UNITED STATES	133,668	79,548	69,101	190,396	472,714

Source: E.H. Pechan Associates, 1982.

Much of the low-sulfur coal in southern West Virginia is considered premium coking coal. Premium coking coal is defined as coking coal with a sulfur content of under 1 percent and ash under 8 percent. Other qualities enhance its value also. Such premium coking coal is generally blended with inferior grade coals to make metallurgical coke for ironmaking.

In ironmaking, coke serves two purposes: (1) supply carbon to produce heat and reducing gas to smelt the ore into iron, and (2) to support the heavy burden of ore, limestone, and other fluxing materials as it travels down the furnace shaft. Hence, besides being low in sulfur and ash itself, a good coke must be physically strong to resist abrasion, impact, and degradation as it travels toward the melting zone of the blast furnace. To blend a good strong coke, some premium coking coal with low volatity is desireable as it will expand when carbonized. High volatile bitiminous coals generally produce the weakest cokes.

As shown in table 21, southern West Virginia contain 78 percent of the country's medium-volatile premium-grade coking coal and 99 percent of the

Table 21: Coking Coal Demonstrated Reserve Base
(million tons)

State and volatile matter[1]	Premium	Marginal	Latent	Total
Alabama:				
High	236.81	462.24	853.39	1,552.44
Medium	1.00	473.86	71.82	546.68
Low	-	-	-	-
Total	237.81	936.10	925.21	2,099.12
Kentucky, East:				
High	4,363.19	3,047.68	589.24	8,000.11
Medium	-	-	-	-
Low	-	-	-	-
Total	4,363.19	3,047.68	589.24	8,000.11
Kentucky, West:				
High	-	-	7,459.79	7,459.79
Medium	-	-	-	-
Low	-	-	-	-
Total	-	-	7,459.79	7,459.79
Maryland:				
High	-	-	-	-
Medium	-	-	-	-
Low	.49	359.74	557.93	918.16
Total	.49	359.74	557.93	918.16
Ohio:				
High	-	1,009.89	16,742.89	17,752.78
Medium	-	-	-	-
Low	-	-	-	-
Total	-	1,009.89	16,742.89	17,752.78
Pennsylvania:				
High	436.74	1,123.94	13,416.67	14,977.35
Medium	-	1,208.14	2,943.44	4,151.58
Low	-	781.48	1,315.77	2,097.25
Total	436.74	3,113.56	17,675.88	21,226.18
Tennessee:				
High	165.22	274.33	406.70	846.25
Medium	-	-	-	-
Low	-	-	-	-
Total	165.22	274.33	406.70	846.25
Virginia:				
High	980.25	594.37	416.22	1,990.84
Medium	375.36	434.22	47.30	856.88
Low	-	-	-	-
Total	1,355.61	1,028.59	463.52	2,847.72
West Virginia:				
High	5,326.67	6,643.91	9,961.67	21,932.25
Medium	1,365.61	318.98	335.18	2,019.77
Low	2,813.63	488.14	409.30	3,711.07
Total	9,505.91	7,451.03	10,706.15	27,663.09
Appalachian Region:				
High	11,508.88	13,156.36	49,846.57	74,511.81
Medium	1,741.97	2,435.20	3,397.74	7,574.91
Low	2,814.12	1,629.36	2,283.00	6,726.48
Grand total	16,064.97	17,220.92	55,527.31	88,813.20

[1] DMMf basis; high volatile--greater than 31 percent volatile matter; medium volatile--greater than 22 percent, equal to or less than 31 percent; low volatile--greater than 14 percent, equal to or less than 22 percent.

NOTE.--Dashes indicate that there is no coking coal DRB in that category.

Table 21: Coking Coal Demonstrated Reserve Base (continued)

State and volatile matter[1]	Premium	Marginal	Latent	Total
Arkansas:				
High	-	-	-	-
Medium	-	-	-	-
Low	24.50	382.00	23.20	429.70
Total	24.50	382.00	23.20	429.70
Illinois:				
High	-	4,070.54	41,899.51	45,968.05
Medium	-	-	-	-
Low	-	-	-	-
Total	-	4,070.54	41,899.51	45,968.05
Indiana:				
High	-	1,842.44	5,744.10	7,586.54
Medium	-	-	-	-
Low	-	-	-	-
Total	-	1,842.44	5,744.10	7,586.54
Iowa:				
High	-	-	1,736.83	1,736.83
Medium	-	-	-	-
Low	-	-	-	-
Total	-	-	1,736.83	1,736.83
Kansas:				
High	-	-	529.39	529.39
Medium	-	-	-	-
Low	-	-	-	-
Total	-	-	529.39	529.39
Michigan:				
High	-	82.61	28.56	111.17
Medium	-	-	-	-
Low	-	-	-	-
Total	-	82.61	28.56	111.17
Missouri:				
High	-	-	3,656.70	3,656.70
Medium	-	-	-	-
Low	-	-	-	-
Total	-	-	3,656.70	3,656.70
Oklahoma:				
High	46.26	122.40	457.72	626.38
Medium	13.81	41.54	91.22	146.57
Low	-	61.26	-	61.26
Total	60.07	225.20	548.94	834.21
Midwest Region:				
High	46.26	6,117.99	54,052.81	60,217.06
Medium	13.81	41.54	91.22	146.57
Low	24.50	443.26	23.20	490.96
Grand total	84.57	6,602.79	54,167.23	60,854.59

Table 21: Coking Coal Demonstrated Reserve Base (continued)

State and volatile matter[1]	Premium	Marginal	Latent	Total
Colorado:				
High	2,025.99	1,669.54	610.65	4,306.18
Medium	-	4.51	-	4.51
Low	-	-	-	-
Total	2,025.99	1,674.05	610.65	4,310.69
Montana:				
High	-	-	1,254.03	1,254.03
Medium	-	-	-	-
Low	-	-	-	-
Total	-	-	1,254.03	1,254.03
New Mexico:				
High	-	1,761.20	6.90	1,768.10
Medium	-	-	-	-
Low	-	9.10	-	9.10
Total	-	1,770.30	6.90	1,777.20
Utah:				
High	782.24	29.67	210.00	1,021.91
Medium	-	-	-	-
Low	-	-	-	-
Total	782.24	29.67	210.00	1,021.91
Washington:				
High	7.90	1.64	123.13	132.67
Medium	-	1.64	3.34	4.98
Low	-	-	-	-
Total	7.90	3.28	126.47	137.65
Wyoming:				
High	-	4,005.16	494.70	4,500.86
Medium	-	-	-	-
Low	-	-	-	-
Total	-	4,005.16	494.70	4,500.86
Western Region:				
High	2,816.13	7,468.21	2,699.41	12,983.75
Medium	-	6.15	3.34	9.49
Low	-	9.10	-	9.10
Grand total	2,816.13	7,483.46	2,702.75	13,002.34

[1] DMMF basis; high volatile--greater than 31 percent volatile matter; medium volatile--greater than 22 percent, equal to or less than 31 percent; low volatile--greater than 14 percent, equal to or less than 22 percent.

Source: Bureau of Mines, 1979.

country's low-volatile premium-grade coking coal. Much of the remaining medium-volatile coking coal is located in the extreme southwestern counties of Virginia. Together, these two States account for 99 percent of the country's medium volatile coal reserve base.

The heavily localized nature of these premium resources is indicated in table 22, showing West Virginia and Virginia coking coal reserves by county. As indicated, the country's reserve of low-volatile coking coal is concentrated in two counties and medium volatile reserves in six. It is also interesting to note that some of these counties have little high

Table 22: Coking Coal Reserves in West Virginia and Virginia by County (million tons)

VIRGINIA

County	High volatile			Medium volatile			Low volatile			County totals		
	Premium	Marginal	Latent	Premium	Marginal	Latent	Pre- mium	Mar- ginal	Latent	Coking coal DRB	Sulfur >3.0% DRB	Premium + marginal DRB
Buchanan.	188.42	114.37	-	313.85	401.05	-	-	-	-	1,017.69	-	1,017.69
Dickenson	162.92	91.43	0.98	-	-	-	-	-	-	255.33	-	254.35
Lee......	28.67	52.49	106.53	-	-	-	-	-	-	187.69	-	81.16
Russel...	256.13	-	187.06	-	-	-	-	-	-	443.19	-	236.13
Tazewell.	-	-	-	61.51	33.17	47.30	-	-	-	141.98	-	94.68
Wise.....	344.11	336.03	121.65	-	-	-	-	-	-	801.84	-	680.19
Total.	980.25	594.37	416.22	375.36	434.22	47.30	-	-	-	2,847.72	-	2,384.20

WEST VIRGINIA

County	High volatile			Medium volatile			Low volatile			County totals		
	Premium	Marginal	Latent	Premium	Marginal	Latent	Premium	Marginal	Latent	Coking coal DRB	Sulfur >3.0% DRB	Premium + marginal DRB
Barbour.........	-	-	490.31	-	-	-	-	-	-	490.31	132.87	-
Boone...........	454.91	1,435.66	340.97	-	-	-	-	-	-	2,231.52	-	1,890.55
Braxton.........	-	-	106.29	-	-	-	-	-	-	106.29	-	-
Brooke..........	-	-	151.75	-	-	-	-	-	-	151.75	-	-
Cabell..........	-	-	-	-	-	-	-	-	-	-	-	-
Calhoun.........	-	-	-	-	-	-	-	-	-	-	-	-
Clay............	-	401.17	124.90	-	-	-	-	-	-	526.07	-	401.17
Doddridge.......	-	-	-	-	-	-	-	-	-	-	-	-
Fayette.........	601.03	31.85	2.10	196.19	-	-	86.70	31.00	-	968.87	-	946.77
Gilmer..........	-	-	169.48	-	-	-	-	-	-	169.48	-	-
Grant...........	-	-	-	-	-	-	-	79.51	247.70	327.21	-	79.51
Greenbrier......	-	-	-	111.39	165.34	-	-	-	-	276.73	-	276.73
Hancock.........	-	-	120.73	-	-	-	-	-	-	120.73	101.04	-
Harrison........	-	-	403.01	-	-	-	-	-	-	403.01	386.14	-
Kanawha.........	582.39	582.40	158.97	-	-	-	-	-	-	1,323.76	-	1,164.79
Lewis...........	-	-	592.04	-	-	-	-	-	-	592.04	546.60	-
Lincoln.........	-	-	-	-	-	-	-	-	-	-	-	-
Logan...........	1,405.59	1,440.59	178.35	-	-	-	-	-	-	3,024.53	-	2,846.18
McDowell........	-	-	-	80.98	16.14	-	818.26	154.52	-	1,127.14	-	1,127.14
Marion..........	-	1,047.12	1,010.81	-	-	-	-	-	-	2,057.93	1,010.81	1,047.12
Marshall........	-	-	1,925.65	-	-	-	-	-	-	1,925.65	1,925.65	-
Mason...........	-	-	117.87	-	-	-	-	-	-	117.87	117.87	-
Mercer..........	-	-	-	-	-	-	46.45	-	-	46.45	-	46.45
Mineral.........	-	-	-	-	-	-	-	15.08	161.60	176.68	68.26	15.08
Mingo...........	823.24	946.13	-	-	-	-	-	-	-	1,769.37	-	1,769.37
Monongalia......	-	150.43	2,900.27	-	-	-	-	-	-	3,050.70	-	150.43
Nicholas........	662.94	286.03	105.73	245.06	-	-	-	-	-	1,299.76	-	1,194.03
Ohio............	-	-	287.69	-	-	-	-	-	-	287.69	287.69	-
Pocahontas......	87.80	-	-	-	-	-	-	-	-	87.80	-	87.80
Preston.........	-	6.84	452.88	-	-	246.46	-	-	-	706.12	-	6.34
Putnam..........	-	-	146.57	-	-	-	-	-	-	146.57	-	-
Raleigh.........	243.86	123.16	-	242.46	-	-	912.86	-	-	1,522.32	-	1,522.32
Randolph........	79.96	67.34	9.55	337.96	-	-	-	-	-	494.79	-	485.26
Roane...........	-	-	-	-	-	-	-	-	-	-	-	-
Summers.........	-	-	-	-	-	-	-	-	-	-	-	-
Taylor..........	-	-	40.04	-	-	-	-	-	-	40.04	-	-
Tucker..........	-	-	-	-	98.63	-	-	-	-	98.63	-	98.63
Tyler...........	-	-	-	-	-	-	-	-	-	-	-	-
Upshur..........	-	67.36	109.45	-	-	-	-	-	-	176.81	16.80	67.36
Wayne...........	-	-	-	-	-	-	-	-	-	-	-	-
Webster.........	203.89	-	-	-	-	34.52	-	-	-	238.41	-	203.89
Wetzel..........	-	-	-	-	-	-	-	-	-	-	-	-
Wyoming.........	181.08	.61	16.26	100.57	38.87	54.26	949.38	208.03	-	1,630.06	-	1,529.54
Total......	5,326.67	6,643.91	9,961.67	1,365.61	316.98	335.24	2,813.63	488.14	409.30	27,063.15	4,593.73	16,955.54

Source: Bureau of Mines, 1979.

volatile premium reserves, the type of coal which would be most likely to increase in demand due to acid rain legislation. Hence, some counties may have to swing their medium volatile coal production from metallurgical markets to steam markets to participate in any "boom" from acid rain legislation.

APPENDIX B: STRUCTURE OF THE EASTERN LOW-SULFUR COAL INDUSTRY

There are two distinct low-sulfur coal industries in the United States— one generally located in the Northern Great Plains and Rocky Mountains of the West, and the other in the central Appalachian mountains of the East. While other deposits of low-sulfur coal do exist, these two locales have prevailed in supplying coal for the steel industry and many of the larger steam-electric powerplants in the Midwest and Gulf Coast States.

Although both areas produce low-sulfur coal, there are extreme differences in the type of coal mined and the mining technology used in each area. Though subject of this report is the eastern low-sulfur coal industry, a brief description of its western counterpart is useful to provide a context for speculation on market interactions.

THE WESTERN LOW-SULFUR COAL (SUBBITUMINOUS) INDUSTRY 25/

The western subbituminous coal industry, concentrated in the Northern Great Plains of Wyoming and Montana, is capital intensive and is characterized by large surface mines. There are very few mines and most are affiliates of either oil (energy) companies or utilities. Huge draglines remove relatively thin cover (overburden averages 30 to 50 feet) and expose coal seams that average 40 to 50 feet thick with some as much as 90 to 100 feet thick. The western mines employ few people, compared to midwestern and Appalachian

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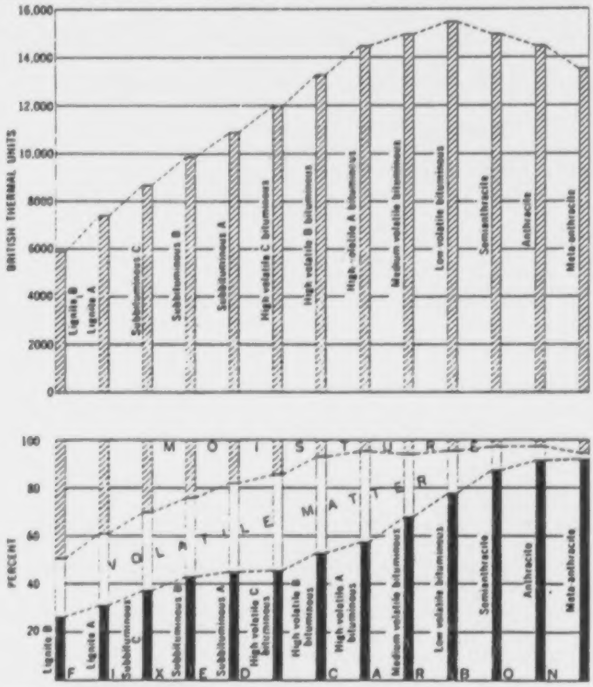
25/ The West also has a low-sulfur bituminous coal industry, particularly in Colorado and Utah. However, the coal is deep-mined like eastern low-sulfur coal, more expensive, and more distant from powerplants in the Midwest. There is no dispute that some of this coal would penetrate eastern markets under acid rain legislation. However, the greatest potential for western coal lies in its subbituminous deposits which have a competitive advantage over other low-sulfur coals in parts of the Midwest. It is this potential that is of central relevance to this report.

mines, but those few people produce tremendous tonnages of coal. Productivity can range as high as 80 to 100 tons-per-man-per-day in some of the Montana, Wyoming, and North Dakota (lignite) mines.

Western low-sulfur coal, however, contains considerably less heat and more moisture than eastern low-sulfur coal. The western coal is ranked as subbituminous and averages around 8,500 to 9,500 Btu's per pound. Figure 18 illustrates the components of western coal compared to higher rank eastern and midwestern coals.

Figure 18: Comparison on Moist, Mineral-matter-free Basis of Heat Values and Proximate Analyses of Coal of Different Ranks



Source: Averitt, Paul. Coal Resources of the United States, U.S. Geological Survey Bulletin 1412, 1975.

Besides detracting from its energy content, the moisture in subbituminous coal poses other problems for users. First, the moisture, combined with volatile matter, can cause spontaneous combustion. Second, the coal is very friable. As it dries out, it breaks down into dust. This can happen during long shipments, or if it is stockpiled too long. These characteristics help explain why so much of it is used by power plants near the surface mines and why, to maximize its efficiency, subbituminous coal should be mined, shipped, and burned continuously.

EASTERN LOW-SULFUR COAL INDUSTRY

The eastern low-sulfur coal industry differs significantly. The coal is different, the structure of the industry is different, and the historical markets are different. These three aspects of the eastern low-sulfur coal industry are discussed below.

Eastern Low Sulfur Coal

Eastern low-sulfur coal is bituminous. A glance at the earlier chart will reveal that bituminous coal has a different proportion of the three basic coal components—fixed carbon, volatile matter, and moisture. Geologically, the coal is older, has been subjected to more heat and pressure, and, as a consequence, more volatiles and moisture (which detract from its energy content) have been driven off over time. A good percentage of eastern low-sulfur coal is actually classified as low-volatile bituminous, and, as the chart illustrates, contains upwards of 14,000 Btus per pound.

Beside a low-sulfur content, eastern low-sulfur coal has many other desirable characteristics which distinguish it as "high purity coal." It is low in ash (the residue of non-combustibles which were originally deposited along with the vegetative material). Some is also low-volatile (i.e., high in fixed carbon) which makes the coal highly sought after for specialized markets, although not generally for steam purposes.

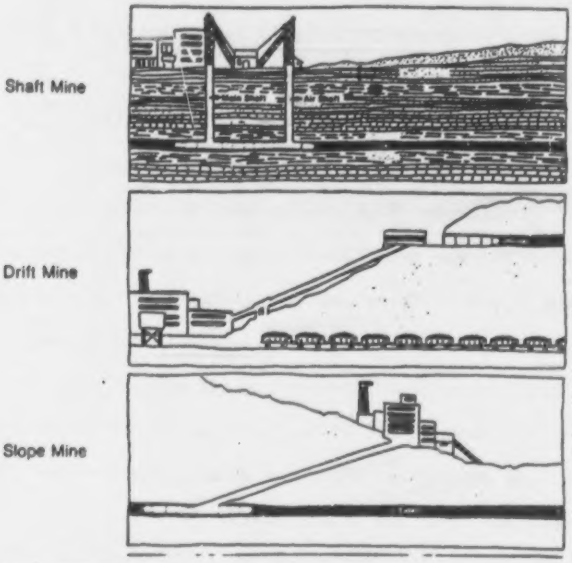
Other properties of eastern low-sulfur coal, while essential for iron-making, can be a hindrance for steam powerplant operations. In particular, most of these coals "coke" to some degree. When these coals are burned, they go through temperature ranges in which the heated coal becomes very sticky and plastic. These highly agglomerating coals adhere to internal boiler parts while they are in these critical firing ranges, Slag is deposited on boiler tubes, and because it reduces heat transfer, can significantly derate a boiler. Ash in the coal, even when it doesn't stick to boiler parts, can abrade them and cause excessive down-time for replacement of tubes and other aft boiler parts.

Structure of the Industry

Geology has dictated a type of mining for eastern low-sulfur coal entirely different than that for Western subbituminous coal. Eastern low-sulfur mines are usually underground, labor intensive, large by eastern mining standards (but small compared to the western behemoths), and (unlike western mines) located in either hilly or mountainous terrain.

Generally, eastern low-sulfur coal deposits are too deep to be mined by surface methods. With today's equipment, the maximum depth for surface mining is about 150 feet. In the Appalachian region, however, most of the low-sulfur coal deposits are several hundred feet deep (with the deepest mines in Alabama approaching 1000 feet). Thus, the coal is mined using one of the underground methods illustrated in figure 19.

Figure 19: Three Types of Bituminous Coal Mines



Source: The National Coal Association, Coal Facts 1978-1979, Washington D.C., Production, p. 17

Without the large equipment used in surface mining, deep mines are generally labor-intensive. This labor intensity results in lower productivity per worker and higher labor costs per ton of coal mined. Whereas the highest productivity for western surface mines approaches 100 tons per-man-per-day, eastern underground mines may average as little as 10 tons per-man-per-day. Consequently, the total production cost for eastern underground coal is generally much higher than for western low-sulfur coal. Current FOB mine prices, as reflected in Coal Week's contract marker, are $6.25 per ton for Wyoming subbituminous coal and about $30.00 per ton for southern West Virginia and eastern Kentucky (District 8) coal 26/. Even when adjusted on a Btu basis, there is still a considerable difference in the minemouth prices of the different coals.

Although small by western standards, low-sulfur eastern mines tend to be large by eastern standards. Most low-sulfur eastern mines are owned by (captive), or affiliated with, major steel producers. Because of this situation, independent (non-captive) low-sulfur coal operations tend to be large in order to compete effectively with the captive mines. Such size offers an opportunity for mines to get lower rail rates from high-volume shipments, and attract lower-cost capital, secured by long-term contracts.

There is, however, a second tier of smaller operators. These operators jump in and out of the spot market (non-contract) as conditions permit. When either domestic or export demand surges, these producers make a little money and then close up shop. However, these small producers may not survive much longer. Growing costs, dwindling demand, competition overseas, increasing legal obligations relating to mine health and safety, and environmental regulations are making it tougher for the smaller operations to exist in today's market. The coal industry is evolving and those producers who cannot streamline their operations, for whatever reason, are finding themselves on the margin and may soon be shed by an industry becoming keenly competitive.

26/ Coal Week, March 19, 1984, p. 5.

Historical Markets

Until recently, the primary market for eastern low-sulfur coal has been the steel industry here and abroad. The exceptionally fine quality of coal from central Appalachia is prized by steelmakers. Despite its higher price and significant advances in metallurgy that have affected the quality and quantity of coke input necessary per ton of hot metal, traditional customers are still willing to pay a significant premium for the best, low-volatile U.S. coals.

In the domestic market, a large number of eastern low-sulfur mines have supplied steel mills in Pittsburgh, Birmingham, and the nucleus of companies in northwestern Indiana. Although major steel mills in the Gary area do maintain some of their own mines in downstate Illinois, the Eastern low-sulfur coals are still an essential component of blended metallurgical coal.

A large percentage of low-sulfur mines are captive operations to fully integrated steel mills. For instance, in 1980, 56 million tons of metallurgical coal was captive to parent steel companies. This represented 37 percent of total captive production of 151.2 million short tons. (Utilities headed the list with approximately 90 million tons.) During that year, the largest producer of captive metallurgical coal was U.S. Steel Corporation with slightly over 14 million short tons from Eastern States, including

Alabama, Kentucky, Pennsylvania, and West Virginia. 27/ Other members of the steel industry with captive mines include Bethlehem, Armco, Jones and Laughlin, Republic, Inland, and Kaiser.

The captivity of low-sulfur mines can be explained by the steel industry's requirements for economic and reliable sources of metallurgical coal for its coking ovens. Not only have they acquired their own sources of coal over the years, but in a comprehensive effort to minimize their costs, they have operated their own coking ovens as well. A recent CRS report on the steel and coking industries indicates that, in 1982, 90 percent of the coke produced in the United States came from integrated operations. 28/ During that year, 39 of the 55 operating coke plants were affiliated with steel companies. Even though a substantial balance of coke continued to be manufactured by independent firms, 70 percent of their output was still earmarked for use in either blast furnaces or foundries. 29/ Thus, as the iron and steel industry goes, so goes the domestic metallurgical coal and coke industry.

Export Market. Until three years ago, the bulk of U.S. coal exports from Eastern mines were also destined for steel mills overseas. Excluding shipments to Canada, as recently as 1980, 90 percent of exports were classified as metallurgical coal. 30/ Unlike most of the mines producing for domestic steel mills, however,

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27/ 1981 Keystone Coal Industry Manual, McGraw-Hill, New York, New York, 1981, p. 720.

28/ Guenther, Gary L. The U.S. Metallurgical Coke Industry: Current Trends in Demand and Supply. CRS Report no. 84-2E, 1984. p. 13.

29/ ibid.

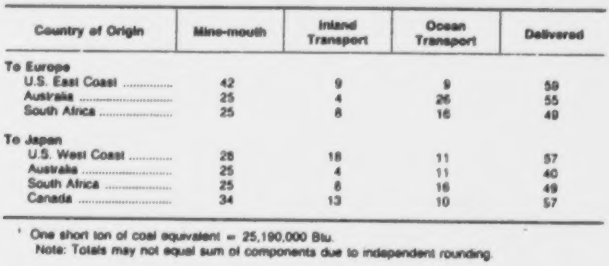
30/ National Coal Association, International Coal 1980. 1982, p. II-14-15 exporters are not captive to their overseas customers. Indeed, most do not even have contracts. The majority of metallurgical coal exporters engage in spot (non-contract) market shipments. Furthermore, instead of dealing directly with the end users, most exporters trade through coal brokers and transshippers who are responsible for collecting, coordinating, and marketing a large number of small shipments into large correctly blended shiploads.

This process results in component coals being blended dockside just prior to loading onto the vessels. Because the loading facilities lack substantial long-term storage areas, most of the coal is stored in the rail cars on sidings and held there until all shipments arrive from the mines. When all of the component coals finally arrive, the ship is docked, the hopper cars are unloaded using rotary dumpers, the coal is blended and conveyed directly to the vessels.

The international steam coal market is highly competitive. Virtually all foreign exporters can produce coal more cheaply than the U.S. because of lower labor and transportation costs. The ability of the United States to compete as effectively as it has results primarily from its excess capacity and quick responsiveness, not its price. Consequently, the U.S. has gained the title of "swing supplier" throughout the world.

Table 23 provide a comparison of component cost of the three major world suppliers of coal. The breakdown revels that, for Eastern U.S. coals destined to Europe, the largest differential occurs in the minemouth price. Inland transporation charges appear to be comparable to those of other exporters. However, for Western U.S. coals destined for Japan, the inland transportation charges appear to be the largest single cost component over Australian and South African coals.

Table 23: Representative Costs of Delivered Steam Coal
(1980 dollars per short ton of coal equivalent)



Country of Origin	Mine-mouth	Inland Transport	Ocean Transport	Delivered
To Europe				
U.S. East Coast	42	9	9	59
Australia	25	4	26	55
South Africa	25	8	16	49
To Japan				
U.S. West Coast	28	18	11	57
Australia	25	4	11	40
South Africa	25	8	16	49
Canada	34	13	10	57

[1] One short ton of coal equivalent = 25,190,000 Btu.
Note: Totals may not equal sum of components due to independent rounding.

Source: DOE-EIA. Prospects for Future World Coal Trade, DOE/EIA 0363, December 1983. p. 12.

It should be noted, however, that transportation charges expressed in per-ton-mile units reveal more about the effects of inland transportation on total delivered costs than dollars per short ton delivered. Rail freight rates and their potential effects on coal use is covered more extensively in the main report.

APPENDIX C: DATA ON AIRCOST ALTERNATIVE COALS

DESTINATION STATE=ALABAMA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	ALABAMA	0.7	11.8	12331	204.3
3	VIRGINIA	0.8	12.8	12374	180.7
4	TENNESSEE	1.1	11.4	12334	146.2

DESTINATION STATE=ARIZONA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	ARIZONA	0.5	9.8	10873	70.8

DESTINATION STATE=ARKANSAS

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	248.5
2	WYOMING	0.4	6.5	8734	163.4
3	WYOMING	0.6	7.8	8962	161.9
8	ILLINOIS	2.3	10.2	11517	137.0

DESTINATION STATE=CALIFORNIA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	UTAH	0.5	10.8	11573	193.2
3	UTAH	0.8	8.0	11813	191.0

DESTINATION STATE=COLORADO

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	121.9
2	WYOMING	0.4	6.5	8734	115.8
3	WYOMING	0.6	7.8	8962	114.3

DESTINATION STATE=CONNECTICUT

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
3	VIRGINIA	0.8	12.8	12374	233.3
5	PENNSYLVANIA	1.4	13.0	12463	177.2

DATA ON AIRCOST ALTERNATE COALS

---------------------- DESTINATION STATE=DELAWARE ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
3	VIRGINIA	0.8	12.8	12374	215.6
5	PENNSYLVANIA	1.4	13.0	12463	180.0

---------------- DESTINATION STATE=DISTRICT OF COLUMBIA ----------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
3	VIRGINIA	0.8	12.8	12374	203.7
8	OHIO	2.3	11.9	11641	201.5

---------------------- DESTINATION STATE=FLORIDA ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	ALABAMA	0.7	11.8	12331	234.8
3	VIRGINIA	0.8	12.8	12374	183.9

---------------------- DESTINATION STATE=GEORGIA ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	ALABAMA	0.7	11.8	12331	184.4
4	TENNESSEE	1.1	11.4	12334	178.5
8	INDIANA	2.1	10.9	10762	139.1
9	INDIANA	3.2	10.6	10896	137.9

----------------------- DESTINATION STATE=IDAHO -----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	128.5
3	WYOMING	0.6	7.8	8962	127.0

---------------------- DESTINATION STATE=ILLINOIS ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	226.1
2	COLORADO	0.5	8.9	10759	225.1
3	VIRGINIA	0.8	12.8	12374	203.7
5	PENNSYLVANIA	1.4	13.0	12463	179.0
6	OKLAHOMA	1.8	10.6	12424	139.6
8	INDIANA	2.1	10.9	10762	152.8

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DATA ON AIRCOST ALTERNATE COALS

DESTINATION STATE=ILLINOIS

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
9	INDIANA	3.2	10.6	10896	151.6

DESTINATION STATE=INDIANA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	256.4
2	MONTANA	0.4	4.2	9521	227.8
3	VIRGINIA	0.8	12.8	12374	200.0
4	KENTUCKY	1.0	11.8	12016	144.8
5	KENTUCKY	1.3	11.8	12104	144.0
8	INDIANA	2.1	10.9	10762	126.9
9	INDIANA	3.2	10.6	10896	125.7

DESTINATION STATE=IOWA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	266.9
2	IOWA	0.4	11.8	10105	140.5
4	NORTH DAKOTA	0.6	9.8	6610	105.3

DESTINATION STATE=KANSAS

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	178.4
2	WYOMING	0.4	6.5	8734	131.2
3	WYOMING	0.6	7.8	8962	129.7
8	MISSOURI	2.2	7.0	12498	110.6

DESTINATION STATE=KENTUCKY

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	205.2
3	WYOMING	0.6	7.8	8962	203.7
4	KENTUCKY	1.0	11.8	12016	172.3
5	PENNSYLVANIA	1.4	13.0	12463	170.8
8	INDIANA	2.1	10.9	10762	132.7
9	INDIANA	3.2	10.6	10896	131.5

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                       DATA ON AIRCOST ALTERNATE COALS

--------------------- DESTINATION STATE=LOUISIANA ----------------------

   SO2         ORIGIN         COAL          COAL       COAL HEAT     COAL PRICE
 CATEGORY      STATE       SULFUR(%)       ASH(%)       BTU/LB       CTS/MMBTU

    1         COLORADO        0.3            6.6         10648          262.1
    2         WYOMING         0.4            6.5          8734          225.4
    3         WYOMING         0.6            7.8          8962          223.9
    4         KENTUCKY        1.0           11.8         12016          203.2
    5         KENTUCKY        1.3           11.8         12104          202.4
    8         ILLINOIS        2.3           10.2         11517          137.2

----------------------- DESTINATION STATE=MAINE ------------------------

   SO2          ORIGIN            COAL         COAL     COAL HEAT     COAL PRICE
 CATEGORY       STATE          SULFUR(%)      ASH(%)     BTU/LB       CTS/MMBTU

    8        WEST VIRGINIA        2.6          11.6       12592          226.3

---------------------- DESTINATION STATE=MARYLAND ----------------------

   SO2       ORIGIN               COAL          COAL     COAL HEAT    COAL PRICE
 CATEGORY    STATE             SULFUR(%)       ASH(%)     BTU/LB      CTS/MMBTU

    4        KENTUCKY             1.0          11.8       12016         217.8
    5        PENNSYLVANIA         1.4          13.0       12463         180.4
    6        MARYLAND             1.7          14.4       12206         158.2

------------------- DESTINATION STATE=MASSACHUSETTS --------------------

   SO2       ORIGIN               COAL          COAL     COAL HEAT    COAL PRICE
 CATEGORY    STATE             SULFUR(%)       ASH(%)     BTU/LB      CTS/MMBTU

    3        VIRGINIA             0.8          12.8       12374         227.0
    5        PENNSYLVANIA         1.4          13.0       12463         182.2

---------------------- DESTINATION STATE=MICHIGAN ----------------------

   SO2         ORIGIN        COAL          COAL       COAL HEAT     COAL PRICE
 CATEGORY      STATE      SULFUR(%)       ASH(%)       BTU/LB       CTS/MMBTU

    2          MONTANA       0.4           4.2          9521          150.2
    8          INDIANA       2.1          10.9         10762          144.8
    9          INDIANA       3.2          10.6         10896          143.6

--------------------- DESTINATION STATE=MINNESOTA ----------------------

   SO2       ORIGIN               COAL          COAL     COAL HEAT    COAL PRICE
 CATEGORY    STATE             SULFUR(%)       ASH(%)     BTU/LB      CTS/MMBTU

    1        COLORADO             0.3           6.6       10648         256.7
    2        MONTANA              0.4           4.2        9521         135.2
    4        NORTH DAKOTA         0.6           9.8        6610         119.2
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                        DATA ON AIRCOST ALTERNATE COALS

-------------------- DESTINATION STATE=MISSISSIPPI --------------------

   SO2         ORIGIN            COAL         COAL      COAL HEAT     COAL PRICE
 CATEGORY      STATE          SULFUR(%)      ASH(%)      BTU/LB       CTS/MMBTU

    1          COLORADO          0.3           6.6        10648         275.7
    2          WYOMING           0.4           6.5         8734         194.4
    3          VIRGINIA          0.8          12.8        12374         177.6
    4          TENNESSEE         1.1          11.4        12334         155.4
    8          ILLINOIS          2.3          10.2        11517         137.4

--------------------- DESTINATION STATE=MISSOURI ---------------------

   SO2          ORIGIN           COAL         COAL      COAL HEAT     COAL PRICE
 CATEGORY       STATE         SULFUR(%)      ASH(%)      BTU/LB       CTS/MMBTU

    1           COLORADO         0.3           6.6        10648         221.2
    2           WYOMING          0.4           6.5         8734         149.7
    3           WYOMING          0.6           7.8         8962         148.2
    6           OKLAHOMA         1.8          10.6        12424         143.7
    8           MISSOURI         2.2           7.0        12498         140.9

--------------------- DESTINATION STATE=MONTANA ----------------------

   SO2          ORIGIN          COAL          COAL      COAL HEAT     COAL PRICE
 CATEGORY       STATE         SULFUR(%)      ASH(%)      BTU/LB       CTS/MMBTU

    2           MONTANA          0.4           4.2         9521          79.7

--------------------- DESTINATION STATE=NEBRASKA ---------------------

   SO2         ORIGIN              COAL        COAL     COAL HEAT     COAL PRICE
 CATEGORY      STATE            SULFUR(%)     ASH(%)     BTU/LB       CTS/MMBTU

    1          COLORADO            0.3         6.6        10648         203.5
    2          WYOMING             0.4         6.5         8734         140.4
    3          WYOMING             0.6         7.8         8962         138.9
    4          NORTH DAKOTA        0.6         9.8         6610          98.4

---------------------- DESTINATION STATE=NEVADA ----------------------

   SO2          ORIGIN          COAL          COAL      COAL HEAT     COAL PRICE
 CATEGORY       STATE         SULFUR(%)      ASH(%)      BTU/LB       CTS/MMBTU

    2           ARIZONA          0.5           9.8        10873         113.9

------------------ DESTINATION STATE=NEW HAMPSHIRE -------------------

   SO2           ORIGIN            COAL        COAL     COAL HEAT     COAL PRICE
 CATEGORY        STATE          SULFUR(%)     ASH(%)     BTU/LB       CTS/MMBTU

    5         PENNSYLVANIA         1.4         13         12463         172.1
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DATA ON AIRCOST ALTERNATE COALS

DESTINATION STATE=NEW JERSEY

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
3	VIRGINIA	0.8	12.8	12374	239.5
4	KENTUCKY	1.0	11.9	12016	233.8
5	PENNSYLVANIA	1.4	13.0	12463	202.5

DESTINATION STATE=NEW MEXICO

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	NEW MEXICO	0.5	13.5	10261	93.8

DESTINATION STATE=NEW YORK

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
4	KENTUCKY	1.0	11.8	12016	248.1
5	PENNSYLVANIA	1.4	13.0	12463	172.2

DESTINATION STATE=NORTH CAROLINA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WEST VIRGINIA	0.7	10.9	12401	61649.0
3	VIRGINIA	0.8	12.8	12374	179.5
4	TENNESSEE	1.1	11.4	12334	158.0

DESTINATION STATE=NORTH DAKOTA

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	MONTANA	0.4	4.2	9521	107.5
4	NORTH DAKOTA	0.6	9.8	6610	83.3

DESTINATION STATE=OHIO

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	213.2
3	VIRGINIA	0.8	12.8	12374	199.2
5	PENNSYLVANIA	1.4	13.0	12463	165.0
8	INDIANA	2.1	10.9	10762	129.8
9	INDIANA	3.2	10.6	10896	128.6

DATA ON AIRCOST ALTERNATE COALS

---------------------- DESTINATION STATE=OKLAHOMA ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	221.7
2	WYOMING	0.4	6.5	8734	153.5
3	WYOMING	0.6	7.8	8962	152.0

---------------------- DESTINATION STATE=OREGON ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	171.1
3	WYOMING	0.6	7.8	8962	169.6

------------------- DESTINATION STATE=PENNSYLVANIA -------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
3	VIRGINIA	0.8	12.8	12374	211.4
5	PENNSYLVANIA	1.4	13.0	12463	157.6
6	MARYLAND	1.7	14.4	12206	150.9

------------------- DESTINATION STATE=RHODE ISLAND -------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
5	PENNSYLVANIA	1.4	13	12463	177.2

------------------ DESTINATION STATE=SOUTH CAROLINA ------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WEST VIRGINIA	0.7	10.9	12401	41122.0
3	VIRGINIA	0.8	12.8	12374	178.1
4	TENNESSEE	1.1	11.4	12334	151.0

------------------- DESTINATION STATE=SOUTH DAKOTA -------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	230.1
2	WYOMING	0.4	6.5	8734	114.6
3	WYOMING	0.6	7.8	8962	113.1
4	NORTH DAKOTA	0.6	9.8	6610	91.4

DATA ON AIRCOST ALTERNATE COALS

---------------------- DESTINATION STATE=TENNESSEE ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	184.3
3	VIRGINIA	0.8	12.8	12374	174.4
4	TENNESSEE	1.1	11.4	12334	164.6

---------------------- DESTINATION STATE=TEXAS ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	244.9
2	WYOMING	0.4	6.5	8734	197.5
3	WYOMING	0.6	7.8	8962	196.0
4	TEXAS	0.6	11.7	6593	84.5
6	TEXAS	0.9	10.0	6700	83.6

---------------------- DESTINATION STATE=UTAH ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	110.1
3	WYOMING	0.6	7.8	8962	108.6

---------------------- DESTINATION STATE=VERMONT ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
5	PENNSYLVANIA	1.4	13	12463	182.2

---------------------- DESTINATION STATE=VIRGINIA ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WEST VIRGINIA	0.7	10.9	12401	92468.0
3	VIRGINIA	0.8	12.8	12374	191.7
4	TENNESSEE	1.1	11.4	12334	161.3

---------------------- DESTINATION STATE=WASHINGTON ----------------------

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	149.8
3	WYOMING	0.6	7.8	8962	148.3
4	WASHINGTON	0.7	16.1	8100	121.3
5	WASHINGTON	0.9	16.6	8100	121.3

DATA ON AIRCOST ALTERNATE COALS

DESTINATION STATE-WEST VIRGINIA

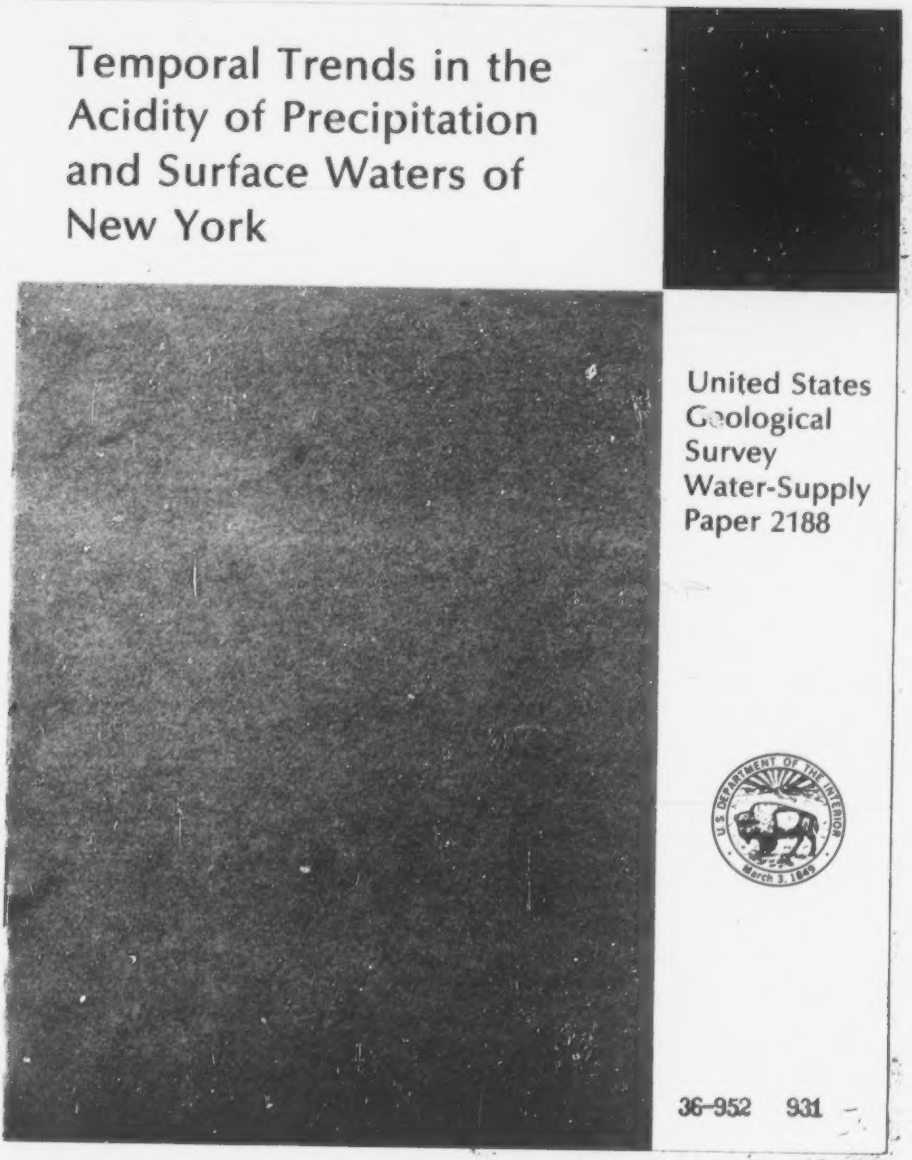
SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WEST VIRGINIA	0.7	10.9	12401	261.9
3	VIRGINIA	0.8	12.8	12374	195.5
5	PENNSYLVANIA	1.4	13.0	12463	172.7
8	OHIO	2.3	11.9	11641	162.0

DESTINATION STATE-WISCONSIN

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
1	COLORADO	0.3	6.6	10648	246.5
2	MONTANA	0.4	4.2	9521	153.7

DESTINATION STATE=WYOMING

SO2 CATEGORY	ORIGIN STATE	COAL SULFUR(%)	COAL ASH(%)	COAL HEAT BTU/LB	COAL PRICE CTS/MMBTU
2	WYOMING	0.4	6.5	8734	83.9
3	WYOMING	0.6	7.8	8962	84.4



Temporal Trends in the Acidity of Precipitation and Surface Waters of New York

United States
Geological
Survey
Water-Supply
Paper 2188

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

36-952 931

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By NORMAN E. PETERS, ROY A. SCHROEDER,
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GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2188

UNITED STATES GOVERNMENT PRINTING OFFICE: 1982

UNITED STATES DEPARTMENT OF THE INTERIOR

JAMES G. WATT, Secretary

GEOLOGICAL SURVEY

Dallas L. Peck, Director

Library of Congress Cataloging in Publication Data

Peters, Norman E.
Temporal trends in the acidity of precipitation and surface waters of New York

(U.S. Geological Survey water-supply paper ; 2188)
1. Hydrometeorology—New York (State) 2. Acid precipitation (Meteorology)—New York (State) I. Schroeder, Roy A. II. Troutman, David E. III Title. IV. Series: Geological Survey water-supply paper ; 2188.
GB2825.N7P47 551.57'09747 81-607082 AACR2

For sale by Distributions Branch
U.S. Geological Survey
604 South Pickett Street
Alexandria, Virginia 22304

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Temporal Trends in the Acidity of Precipitation and Surface Waters of New York

By Norman E. Peters, Roy A. Schroeder, *and* David E. Troutman

Abstract

Statistical analyses of precipitation data from a nine-station monitoring network indicate little change in pH from 1965–78 within New York State as a whole but suggest that pH of bulk precipitation has decreased in the western part of the State by approximately 0.2 pH units since 1965 and increased in the eastern part by a similar amount. This trend is equivalent to an annual change in hydrogen-ion concentration of 0.2 microequivalents per liter.

An average annual increase in precipitation quantity of 2 to 3 percent since 1965 has resulted in an increased acid load in the western and central parts of the State.

During 1965–78, sulfate concentration in precipitation decreased an average of 1–4 percent annually. In general, no trend in nitrate was detected. Calculated trends in hydrogen-ion concentration do not correlate with measured trends of sulfate and nitrate, which suggests variable neutralization of hydrogen ion, possibly by particles from dry deposition. Neutralization has produced an increase of about 0.3 pH units in nonurban areas and 0.7 pH units in urban areas.

Statistical analyses of chemical data from several streams throughout New York suggest that sulfate concentrations decreased an average of 1 to 4 percent per year. This decrease is comparable to the sulfate decrease in precipitation during the same period. In most areas of the State, chemical contributions from urbanization and farming, as well as the neutralizing effect of carbonate soils, conceal whatever effects acid precipitation may have on pH of streams.

INTRODUCTION

During the last 30 to 50 years, a significant decrease in pH of atmospheric precipitation[1] has been noted in Europe (Barrett and Brodin, 1955; Oden, 1976; Wright and Gjessing, 1976) and in much of North America (Gambell and Fisher, 1966; Cogbill and Likens, 1974; Cogbill, 1976; Dillon and others, 1978). Acid atmospheric precipitation has been defined as rain or snow having a pH less than 5.6 (Barrett and Brodin, 1955; Likens, 1976), the value of pure water in equilibrium with ambient levels of atmospheric carbon dioxide. During the late 1970's, the average pH of precipitation calculated from the average hydrogen-ion concentration in much of the Northeastern United States ranged from 4.0 to 4.2 annually (Likens, 1976). The decrease in the pH of precipitation from a background of 5.6 to 4.0 is equivalent to a 40-fold increase in hydrogen ion concentration. Because long-term, continuous records of precipitation quality are not available, it is difficult to determine precisely the time of onset of acid precipitation in New York, although it is believed to have been between 1930 and 1950 (Cogbill and Likens, 1974). Similarly, the paucity of precipitation-quality records prior to 1964, when the first monitoring stations were installed, makes delineation of historical trends difficult.

In the absence of complete long-term precipitation-quality records, previous studies of trends in precipitation chemistry were either based on short periods of record (Pearson and Fisher, 1971; Likens, 1972; Tabatabai and Laflem, 1976; Richardson and Merva, 1976), were done at only one or two sites (Jacobson and others, 1976; Liljestrand and Morgan, 1978; Lewis and Grant, 1980), or were based on discontinuous records (Cogbill and Likens, 1974). Since 1965, the U.S. Geological Survey has operated a network of nine precipitation-quality monitoring stations in New York State; these provide some of the longest continuous records of precipitation quality in the United States.

Purpose and Scope

The purpose of this report is to analyze 13 years of data (1965–78) from the nine collection sites in New York to assess trends in precipitation acidity and to determine to what extent these trends are local or regional. A trend analysis of selected streams having continuous long-term water-quality records and representing a variety of land uses is included to evaluate effects of acid precipitation on surface-water quality.

Acknowledgments

Thanks are extended to the many observers who collected the data and maintained the sampling equipment. Data on rainfall quantity at each site were provided by the National Weather Service; financial support was provided by the New York State Department of Environmental Conservation and the New York State Energy Research and Development Authority.

SOURCES AND EFFECTS OF ACID PRECIPITATION

Sulfuric acid, nitric acid, and, to a much lesser extent, hydrochloric acid are the predominant strong mineral acids that contribute to the acidity of precipitation (Likens and Bormann, 1974; Galloway and others,

---

[1] The term "precipitation" in this report refers to atmospheric, not chemical, precipitation.

1976). These acids are formed when sulfur and nitrogen oxides oxidize and (or) hydrolyze in the presence of water.

Natural sources of sulfate in the atmosphere include aerosols from sea spray, volcanic emissions, and readily oxidized hydrogen sulfide released from the anaerobic decomposition of organic matter in swamps and bogs (Robinson and Robbins, 1970a). Natural sources of nitrogen include nitrogen oxides produced by micro-organisms in soils and, to a lesser extent, the fixation of nitrogen as oxides by lightning (Robinson and Robbins, 1970b). Large increases in the free-acid concentration[2] (decrease in pH) of precipitation result from emissions of sulfur and nitrogen oxide gases to the atmosphere from the combustion of fossil fuels (Likens, 1976; Shinn and Lynn, 1979). Galvin and others (1978) and Samson (1978), tracing storm trajectories, attributed high sulfur dioxide concentrations to sources south and west of New York, and implied that these high concentrations are derived from air masses that stagnate over the heavily industrialized areas of the Ohio River valley and eventually advect into New York and the Northeast.

In Europe, where precipitation data have been collected by the European Atmospheric Chemistry Network and International Meteorological Institute since 1940 (Eriksson, 1960), increases in the hydrogen-ion (free-acid) concentration of precipitation seem to have been associated with increases in atmospheric sulfate concentrations (Oden, 1976; Granat, 1978). In contrast, data collected in central New York and at Hubbard Brook Experimental Forest in New Hampshire indicate that sulfate concentration has decreased by as much as 70 percent since 1950, yet sulfate is still the predominant anion in precipitation in most of the Northeast, and that much of the concentration decrease occurred between 1950 and 1955 (Likens and Bormann, 1974; Likens and others, 1976). However, the concentration of nitrate in precipitation has increased in the Northeast, particularly since the early 1960's (Likens and Bormann, 1974; Cogbill and Likens, 1974).

The low pH of precipitation in North America is most pronounced in the Northeast, including New York State. Likens and Bormann (1974) reported an annual mean pH of 4.03 in wetfall at Hubbard Brook Experimental Forest in New Hampshire for 1970–71 (pH of wetfall in central New York during the same period ranged locally from 3.91 to 4.02). In addition, Miller and others (1978), from a trajectory analysis of storms in Central New York, associated sources of high sulfur southwest of this area with acid precipitation.

Decreases in pH of surface water as a result of acid precipitation are most pronounced in terrain lacking carbonate rock, which neutralizes excess hydrogen concentration more rapidly than do other rock types. Thus, areas containing crystalline or metasedimentary bedrock and lacking carbonate rock have been identified as sensitive to acid precipitation (Hendrey and others, 1980). The Adirondack Mountain region of northeast New York is such an area. In a synoptic survey of lakes in the Adirondacks, Schofield (1976) found that 50 percent of the lakes at high elevation (above 600 m) had a pH less than 5.0 and that 90 percent of these no longer contained fish. A similar survey of many of these lakes from data collected during 1929–37 revealed that only 4 percent had pH values less than 5.0 or were devoid of fish. Recent synoptic studies of lakes in Scandinavia have revealed similar trends (Wright and Gjessing, 1976).

Although nearly all streams undergo some degree of neutralization through interaction with the soils and bedrock, the smaller headwater streams are buffered mainly by aluminum hydroxides rather than by carbonates, a condition that results in less neutralization (Johnson, N. M., 1979). In the Adirondack Mountains of New York, where appreciable quantities of acid precipitation are stored in the winter snowpack, many streams and lakes, even in well-buffered areas, experience a sharp temporary decrease in pH during the spring snowmelt, when large quantities of concentrated acid accumulated during the winter are released from the snowpack and transported by meltwater (Galloway and others, 1980). This phenomenon was also observed in Norway (Johannessen and Henriksen, 1978).

Even though delineation of trends in pH has been hindered by a lack of continuous or long-term records and by seasonal fluctuations that are difficult to differentiate during analysis of the data, studies by C. L. Schofield (Cornell Univ., Department of Natural Resources, written commun., 1975) on two Adirondack streams and by A. H. Johnson (1979) on two headwater streams in the New Jersey Pine Barrens indicate trends of decreasing pH; data from Hinckley Reservoir in the Adirondack Mountains reveal a similar decrease (C. L. Schofield, written commun., 1975). Even on Long Island, N.Y., precipitation is reported to have a significant influence, as indicated by a recent decline in pH of water from the major confined (Magothy) aquifer (Pearson and Fisher, 1971).

Although the disappearance of fish from lakes is the most dramatic example of adverse effects of acid precipitation (Schofield, 1976, 1977), other harmful effects have been suggested, including increased chemical weathering of manmade structures and possibly deleterious effects on human beings (Likens, 1976, and references therein). In addition, toxic levels of lead and copper have been found in tap water from several communities using surface-water supplies in unbuffered areas of New York (Turk and Peters, 1977); the elevated concentrations are attributed to increased dissolution of heavy metals from the pipes and soldered joints of the distribution system.

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[2] The activity of hydrogen ion is equal to 10^{-pH}. In dilute solutions such as atmospheric precipitation, activity is nearly equal to concentration. Hence, hydrogen-ion (also called free-acid) concentration is calculated in this study from the measured pH and is assumed to be equal to the activity.

The effect of acid precipitation on biological systems is largely unknown, and study results appears somewhat contradictory. Some studies suggest that forest productivity is reduced and agricultural yields are decreased (Likens, 1976, and references therein), while others indicate certain beneficial effects. For example, the increased concentrations of sulfate and nitrate in acid precipitation may provide an important source of plant nutrients to deficient ecosystems (Barica and Armstrong, 1971; Schindler and others, 1976) and could possibly increase crop yields (Maugh, 1979).

METHODS

Network Design

Precipitation

The precipitation-quality monitoring network in New York State, operated by the U.S. Geological Survey in cooperation with the New York State Department of Environmental Conservation, was designed to provide data and continuous records on atmospheric contributions for use in hydrologic and geochemical studies. The network consists of nine sampling stations; eight are within New York, the other is in Pennsylvania near the New York State border (fig. 1). Details on the selection of sites are described by Pearson and Fisher (1971). In this study, bulk collectors (Whitehead and Feth, 1964) were established to obtain a monthly composite sample of wet plus dry fallout. The precipitation network contains two coastal stations, two urban stations (one of which is also coastal), and six rural inland stations.

Surface Water

The surface-water stations used in this study are distributed uniformly across the State (except on Long Island) and were selected to represent a variety of land uses. All stations had complete records of discharge and water quality for the period to be analyzed.

Location of the precipitation and surface-water sites, and also the predominant bedrock type underlying each site, is shown in figure 1. Additional information about the precipitation sites is given in table 1; information on surface-water sites is given in table 2.

Sampling Techniques

Precipitation

The type of precipitation collector used in 1965 (fig. 2A) consisted of a glass collection funnel with a fritted glass disk at the base. Water entering the funnel discharged through Tygon[1] tubing into a polyethylene collection bucket. The unit was thermostatically con-

Table 1.—Period of record and predominant land use at precipitation-monitoring sites
[Site locations are given in fig. 1]

Site	Latitude (North)	Longitude (West)	Period of record	Predominant land use	Remarks
Coastal					
Mineola	40°44′17″	73°38′17″	Nov. 1965–Aug. 1976	Urban	Located on office rooftop.
Upton	40°52′16″	72°53′20″	Aug. 1965–Aug. 1973 Mar. 1975–Sept. 1979	Residential	Refrigerated old-style sampler.
Urban					
Albany	42°44′35″	73°48′30″	Aug. 1965–Sept. 1978	Urban	Located at Albany airport.
Rural inland					
Rock Hill	41°37′25″	74°31′17″	Aug. 1965–Sept. 1978	Residential, woodlands	Located in back yard.
Athens, Pa	41°55′31″	76°31′35″	do	Agricultural	Located on large dairy farm and near fuel pump.
Salmanca	42°06′00″	78°45′00″	do	Woodlands	Located at Allegany State Park visitor center.
Mays Point	42°59′55″	76°45′45″	do	Agricultural, wetlands	Located on Erie Barge Canal.
Hinckley	43°18′35″	75°06′35″	do	Woodlands	Located near reservoir.
Canton	44°34′40″	75°06′40″	do	Agricultural	Located on agricultural extension station.

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[1] Use of brand names in this report is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.

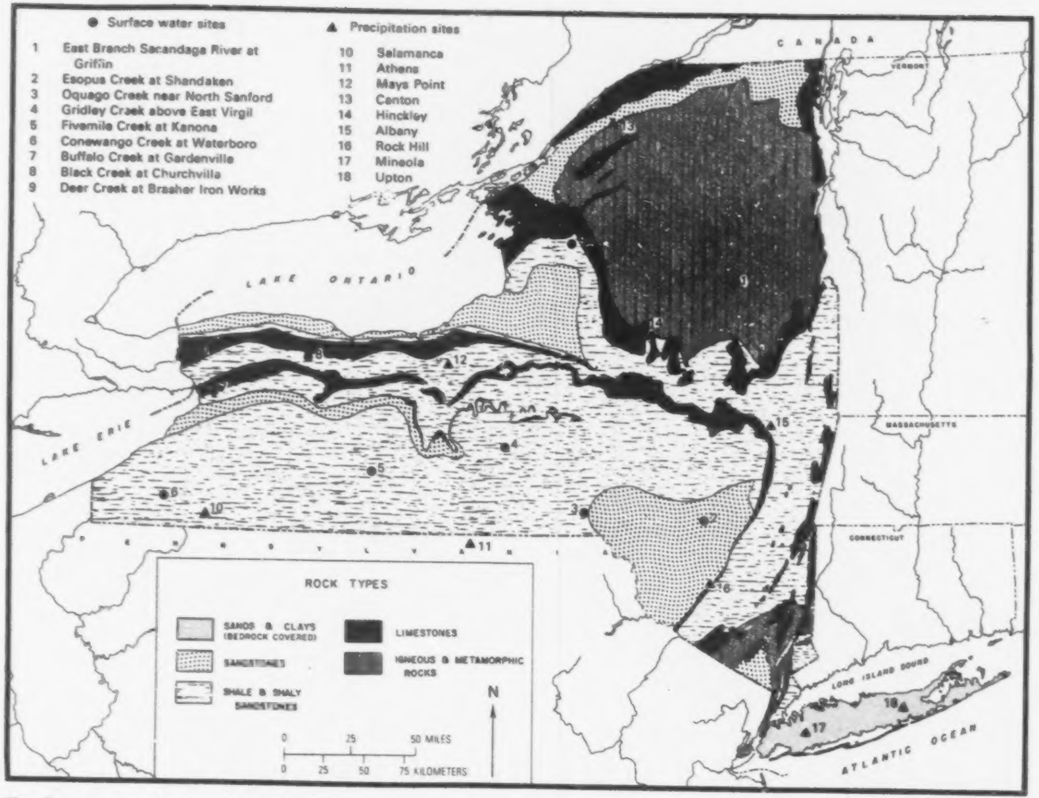
● Surface water sites
1 East Branch Sacandaga River at Griffin
2 Esopus Creek at Shandaken
3 Oquago Creek near North Sanford
4 Gridley Creek above East Virgil
5 Fivemile Creek at Kanona
6 Conewango Creek at Waterboro
7 Buffalo Creek at Gardenville
8 Black Creek at Churchville
9 Deer Creek at Brasher Iron Works
▲ Precipitation sites
10 Salamanca
11 Athens
12 Mays Point
13 Canton
14 Hinckley
15 Albany
16 Rock Hill
17 Mineola
18 Upton
CANADA
VERMONT
MASSACHUSETTS
CONNECTICUT
LAKE ONTARIO
LAKE ERIE
LONG ISLAND SOUND
ATLANTIC OCEAN
PENNSYLVANIA
ROCK TYPES
SANDS & CLAYS (BEDROCK COVERED)
SANDSTONES
SHALE & SHALY SANDSTONES
LIMESTONES
IGNEOUS & METAMORPHIC ROCKS
0 25 50 MILES
0 25 50 75 KILOMETERS
N

Figure 1.—Location of precipitation and surface-water-measurement sites and associated bedrock geology (modified from Thompson, 1966, p. 24; reproduced with permission of publisher).

Table 2. – Period of record and basin characteristics of surface-water measurement sites
[Locations are given in fig. 1]

Station name	USGS station No	Drainage area (km²)	Period of record	Land use,[1] in percent				Remarks
				Agricultural	Woodlands	Urban	Residential	
East Branch Sacandaga River at Griffin.	01319000	295	Aug. 1965 May 1975	<1	99	<1	<1	
Esopus Creek at Shandaken.	01362198	154	Aug. 1963-Sept. 1979	<1	97	<1	2	USGS benchmark station; some months missing from record.
Oquaga Creek near North Sanford.	01425675	12.2	Mar. 1971-Aug. 1979	14	85	<1	<1	Some months missing from record.
Gridley Creek above East Virgil.	01509150	26.9	Dec. 1974-Sept. 1979	47	52	<1	<1	
Fivemile Creek near Kanona.	01528000	173	Mar. 1966-May 1975	39	60	<1	<1	
Conewango Creek at Waterboro.	0301300	757	Oct. 1965-Oct. 1975	48	51	<1	<1	
Buffalo Creek at Gardenville.	04214500	373	July 1966-May 1975	47	46	3	4	
Black Creek at Churchville.	04231000	319	Aug. 1965-May 1975	72	25	<1	2	Slight regulation due to pumping.
Deer River at Brasher Iron Works.	04269500	490	--------do--------	30	69	<1	<1	

[1] Land-use data were obtained by digitizing the associated land-use categories for the stream basins from 1968 Land Use and Natural Resources Inventory (LUNR) map overlays.

trolled to maintain a temperature above 4°C so that snow entering the funnel would melt. The fritted glass disk was replaced each month. Some collectors contained a plug of spun glass above the fritted glass disk to reduce clogging of the disk. Additional details of the design are described by Gambell and Fisher (1966).

Beginning in 1977, a new type of collector (fig. 2*B*) became available and gradually replaced the old ones. The newer collectors use a polyethylene funnel that discharges through silastic tubing into a teflon collection bottle. A loop in the silastic tubing provides a vapor lock to retard evaporation. The sampler is thermostatically controlled for snow collection, as are the older-style collectors. The only site at which an old-style collector remained in use as of 1980 was at Upton, on Long Island (fig. 1).

Surface Water

Water-quality and water-discharge data used in the surface-water trend analyses were collected by the U.S. Geological Survey at gaged sites. (Site locations are shown in fig. 1.) Samples for water-quality analysis were collected at least monthly by methods described by Brown and others (1970); discharge at the time of sample collection was measured by standard procedures for stream gaging (Carter and Davidian, 1968).

Analytical Techniques

Data used in this report include concentrations of sodium, potassium, calcium, magnesium, pH, ammonium, nitrate (plus nitrite), chloride, sulfate, bicarbonate (or alkalinity)[4], and specific conductance. (These data are published in U.S. Geological Survey, 1964-75; 1976-80.) Precipitation-quantity data were obtained from records of National Weather Service gages at or near the network sites (U.S. National Oceanographic and Atmospheric Administration, 1965-78). Surface-water analyses were, in general, done on monthly grab samples filtered through a 0.45-μm (micrometer) membrane filter. Monthly bulk precipitation samples were decanted but not filtered.

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[4] Bicarbonate concentration of precipitation is not included in this report because samples were analyzed for bicarbonate only on a sporadic basis.

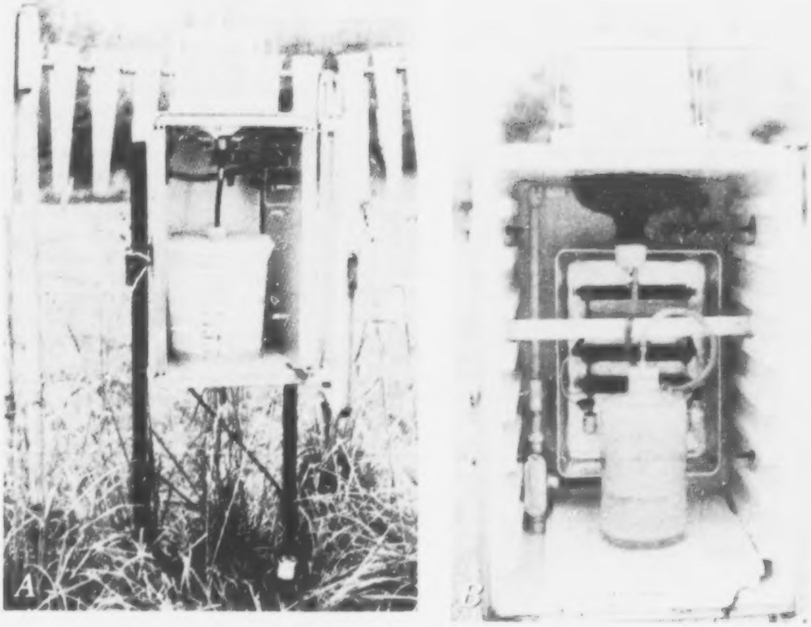

Figure 2.—Apparatus used to collect bulk precipitation samples. A, Collector used from 1965-77. B, Collector used since 1977.

All conductance and pH measurements were made by the U.S. Geological Survey in Albany, N.Y. Before 1977, analyses for the other chemical constituents were made in the Albany laboratory; thereafter they were made in the Survey's National Water Quality Laboratory in Atlanta, Ga. Methods used for chemical analysis are described by Skougstad and others (1979). Although analytical procedures have been modified during recent years through technical advances, it is beyond the scope of this report to discuss these changes in detail.

Because chemical concentrations are typically much lower in precipitation than in surface water, measured chemical concentrations of precipitation samples may be less precise than those of surface water. Also, detection limits were lower in the later part of this study, which suggests that the recent concentration data may be more accurate than the earlier values. However, precision and accuracy of pH and conductance measurements have not changed since 1965.

Data Editing

Precipitation

The data used in this study were modified to provide single monthly values (where possible) for trend analysis. Precipitation samples were designated by month of collection. Because the period of sample collection did not always coincide with the calendar month, each sample was designated by the month containing the greatest number of collection days. In the few instances (less than 5 percent) when precipitation quantity was not available from the nearby Weather Service gage, quantity was estimated from the nearest adjacent gage, typically within 20 miles of the collector.

Stream Discharge

Daily mean discharge values were used in less than 2 percent of the cases; otherwise instantaneous discharges were used. When multiple monthly chemical data were collected, only the first observation was used in trend analysis. In the few instances in which data from a specific month were unavailable, data from the previous or following month were used. This constituted fewer than 2 percent of the observations at any given station.

Nitrogen in Precipitation and Surface Water

The precipitation samples analyzed for nitrogen species in this study varied in chemical state and physical phase. To obtain a continuous record of sufficient length, the results were combined into a single data set represented as nitrate. Accordingly, nitrite values, when available, were included with nitrate. The error introduced by this procedure was negligible because nitrite seldom constitutes more than 5 percent of nitrate concentration. In addition, results for dissolved and total species are assumed to be interchangeable. The extremely high solubility of nitrate insures that dissolved and total concentrations should be equal.

Surface-water data used in this study included only the nitrate, nitrite, and ammonium values obtained after July 1971.

Conductance and Electroneutrality of Precipitation and Surface Water

The initial step in screening the data was to identify outlying values and then to review available field and laboratory notes and correct transcription errors. The next step was to remove anomalously low pH values (pH is generally difficult to measure accurately in solutions of low ionic strength, such as precipitation). To determine the lowest acceptable pH value, a maximum permissible hydrogen-ion concentration (representing minimum pH value) was calculated.[5] Because specific conductance, in micromhos per centimeter (μmho/cm), of hydrogen ion in dilute solution is about 380 times its concentration, in milliequivalents per liter (meq/L),[6] the maximum permissible concentration of hydrogen ion was obtained by dividing measured specific conductance by 380. If the measured concentration exceeded the calculated value by more than 25 percent,[7] the value was deleted from the data set. This procedure eliminated about 5 percent of the pH measurements.

The final step, deletion of anomalous chemical concentrations, was based on the requirement of electroneutrality that cation equivalents must equal anion equivalents. If the difference between cation and anion equivalents in a sample exceeded the total ion equivalents by 25 percent or more, all results for that sample other than pH and conductance were deleted from the data set. In calculations for surface-water samples, cations considered were sodium, potassium, calcium, and magnesium; anions considered were bicarbonate, chloride, sulfate, and nitrate. In calculations for precipitation samples, cations were sodium, potassium, calcium, magnesium, ammonium, and hydrogen; anions were chloride, sulfate, and nitrate. If data on the concentration of any of these above constituents were unavailable, the test was not applied. All data-editing procedures were intended to minimize the potential for major errors.

Statistical Techniques

Regression Analysis

Least-squares regression analysis was used to determine the straight line best representing the set of points on a plot of concentration of a selected constituent against time. The slope of this line was taken as a measure of linear trend. Regressions were also used to determine the relationship between chemical concentration and stream discharge (or some function of discharge) and between chemical concentration of precipitation samples and precipitation quantity (or some function of quantity).

Precipitation Analysis

Chemical constituents of a bulk precipitation sample are derived from wetfall, dryfall, and gaseous transfer; chemical concentrations of a sample during a rainfall vary with quantity and duration of the event (Kennedy and others, 1979). The initial washout of ions from the atmosphere during a storm tends to concentrate chemical constituents in the sample, but these become diluted as the storm continues. It was anticipated that chemical concentration of monthly bulk samples might vary disproportionately with precipitation quantity, as expressed in equation 2; the logical alternative would be a direct relationship, as expressed in equation 1.

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[5] This procedure was based on the premise that no other constituents were contributing to measured specific conductance. In fact, other cations and anions would raise the conductance and in turn raise the calculated maximum permissible hydrogen-ion concentration. The degree of error resulting from this assumption is variable but on the order of 10-15 percent at low pH.

[6] At infinite dilution and 25° C, the equivalent conductances (in micromhos per centimeter per equivalent) of the following ions are hydrogen, 350; sulfate, 79; nitrate, 71. These equivalent conductances decrease with an increase in ionic strength of a solution.

[7] Because the contribution of other ions was ignored, the actual constraint is closer to 35-40 percent, which is equivalent to deleting values that were in error by more than 0.2 pH units.

$$\text{Linear relationship: } C_i = aQ + b, \qquad (1)$$
$$\text{Hyperbolic relationship: } C_i = (a/Q) + b, \qquad (2)$$

where

C_i is the concentration,
Q is the precipitation quantity,
a is the slope of regression line, and
b is the intercept value.

If neither the hyperbolic nor the linear equation produces results that are significant to at least the 90-percent confidence level, or level of significance $\alpha < 0.1$, the null hypothesis that concentration is independent of quantity is not rejected, and predicted concentration is set equal to the mean concentration (equivalent to eq 1 with a slope of zero) for subsequent use in a nonparametric statistical test for temporal trends.

Surface-water Analysis

A general hyperbolic equation formulated by Johnson and others (1969) provided a more rigorous theoretical basis than did equations 1 or 2 for the mixing of a two-component system (ground-water and surface-water contributions):

$$\text{General hyperbolic relationship: } C_i = [1/(1 + \beta \cdot Q)]a + b, \qquad (3)$$

where

β is a constant, described in the section Relationship Between Chemical Composition and Discharge, and
Q is stream discharge.

Equation 3 was used in this study for analysis of surface-water data with β values increasing from $10^{-5.5}$ to $10^{-2.0}$ km$^2 \cdot$ d/m^3 in increments of $10^{0.5}$ (a total of eight possibilities).

Statistical Considerations

Residual values, which are the difference between predicted and measured concentrations from the best equation, as determined by the maximum R^2 (square of correlation coefficient), were selected for application in the nonparametric seasonal Kendall statistical test described below. R^2 is the proportion of the total variance in concentration explained by the regression model. (In tables throughout this report, R^2 is multiplied by 100 to express it as a percentage.)

The level of significance of linear regression relationships is established by computing the t-test statistic **for the correlation coefficient (r) from a normally distributed population whose correlation coefficient is zero on the assumption that both the distributions of C_i are normal for each Q, and the variances for these distributions are constant for each Q. The significance of r is related to the number of observations. Hence, for a given level of significance, the required r value decreases as the number of observations increases. Furthermore, if temporal dependence exists among the data, the number of observations on which the significance of the relationships was based will be fewer than those used, and will result in nonsignificance for some relationships that are claimed to be significant. A more detailed discussion of levels of significance and related statistical concepts is given in Dixon and Massey (1969).**

Nonparametric Seasonal Kendall Test

The seasonal Kendall test (Hirsch and others, 1982) is used to test whether the residuals from the regression of C_i on $f(Q)$ show a significant time trend. This type of test uses only the relative ranking of data and is advantageous in analyses of water-quality data that reflect seasonal variations or point-source loadings.

The seasonal Kendall test was used to compare residual values obtained from equations 1-3 for a given month with those of the same month of the most recent succeeding year for which data were available. If the comparison was positive (the succeeding value was higher), a value of + 1 was recorded; if negative, a value of − 1 was recorded. Summing all positive values and dividing by the number of entries yielded the test statistic, a fraction representing the temporal trend. This value (Kendall's τ) was then compared to the standard normal distribution function to establish the level of statistical significance. Using an average of the actual values rather than + 1 or − 1 gave the slope of the trend.

RESULTS AND DISCUSSION

Precipitation

Chemical Composition of Samples

As stated previously, the pH of precipitation in bulk collectors is a net result of chemical and biological interactions among materials contributed in wetfall and dryfall and through gaseous exchange. Materials are contributed from both manmade and natural sources, including sea spray, aerosols, dust, and ions dissolved in wetfall.

pH

According to a precipitation model proposed by Granat (1972), a simple stoichiometric relationship among major ions can be used to predict hydrogen-ion concentration. Because the ions derived from sea-salt particles (mostly sodium and chloride and some magnesium and sulfate) are already neutralized, hydrogen ions are the difference between the remaining acid-forming and base-neutralizing ions. The acid-forming anions (sulfate and nitrate) are partly neutralized by "excess" cations (those not included in the sea-salt component); hence, hydrogen-ion concentration can be calculated as the excess of anion over cation (excluding hydrogen) equivalents (electroneutrality). Despite complicating factors, such as anomalous materials introduced by dryfall, the 1-month storage period at ambient field conditions, and changes in collection and analytical methods over the years, results of this calculation show reasonably close agreement between calculated and measured hydrogen-ion concentrations (table 3). The largest difference, 25 μeq/L (microequivalents per liter), was in samples from Salamanca, in southwestern New York (fig. 1).

Mean chemical composition of precipitation in the nine-station precipitation network is given in table 3. For comparison, the volume-weighted mean composition of precipitation at three locations in central New York, as reported by Cogbill and Likens (1974), is included. Cogbill and Likens' data were based on storm-by-storm sampling between September 1972 and August 1973, about the midpoint of the Geological Survey's collection period. Data in table 3 indicate that pH in the Survey's network, excluding urban sites, was 0.2 to 0.3 pH units higher than that in Cogbill and Likens' study. This difference corresponds to a nearly 50-percent lower hydrogen-ion concentration in the Survey's records, which is 30 to 40 μeq/L less than in Cogbill and Likens' record. The lower hydrogen-ion activity in the Survey's data may be due to neutralization by dryfall in the bulk sample. Alkaline-earth elements (calcium and magnesium) are the predominant cations, followed at most stations by sodium, ammonium, and potassium.

Ion Concentration

Despite substantial differences between collection methods of the Geological Survey and of Cogbill and Likens (1974), the chemical composition of samples was surprisingly similar; the few large differences may generally be attributed to local influences. Major chemical characteristics of precipitation samples are described in the following paragraphs.

Ratio of sulfate to nitrate at the Geological Survey stations was about 3:1, and at Cogbill and Likens' central New York stations, about 2:1. However, the analytical technique for nitrate at the Geological Survey changed in spring 1969. A comparison of mean nitrate values for the time preceding this date with values thereafter indicates that the more recent values are about four times larger than the earlier ones (table 3). The ratio of sulfate to nitrate in the more recent data is 2.5:1, lower than that for the complete record but greater than the 2:1 ratio recorded by Cogbill and Likens (1974). No reason for this difference is apparent, although the higher ratio in the Survey's data reflects a combination of slightly higher sulfate along with lower nitrate concentrations.

Chloride concentrations varied widely from place to place; the lowest recorded values were at inland stations, such as Hinckley and Canton, and were about the same as at Cogbill and Likens' stations, which were also inland. Chloride concentrations at Mineola and Upton, near the coast, were markedly higher than at inland sites as a result of proximity to the ocean. The elevated concentrations of sodium and chloride at Albany may indicate contributions from local sources, perhaps road salt.

The high concentrations of magnesium in the coastal samples are attributed to marine sources, especially at Upton, which is less urbanized than Mineola. Subtracting the sea-salt contribution at Upton (on the assumption that the ratio of other ions to chloride in samples is identical to that in sea water and that chloride is entirely marine derived) reduces the mean calcium concentration from 0.024 to 0.022 meq/L, magnesium from 0.016 to 0.006 meq/L, sodium from 0.050 to 0.005 meq/L, and sulfate from 0.074 to 0.069 meq/L. The concentrations after subtraction of sea salt are comparable to inland concentrations.

Although Mineola and Upton are at similar distances from the ocean, Upton is less urbanized, and its collector is of the older type, in which a fritted glass filter is installed beneath the collection funnel and the sample is refrigerated. Ammonium and nitrate concentrations at Upton were lower than at other sites, which may have been a consequence of reduced biological activity in the refrigerated collector.

The impact of urbanization on bulk precipitation chemistry is seen in samples from both Mineola and Albany. The net effect at Albany was a reduction in hydrogen-ion concentration to one-fourth that at Cogbill and Likens' (1974) central New York sites and half that of the nonurban Geological Survey sites – an increase of several tenths of a pH unit. The major element contributing to neutralization at Albany was calcium, as indicated by its extremely high concentration in relation to the other cations. Apparently, the elevated levels of particulate material in an urban atmosphere were sufficient to neutralize precipitation in the bulk collector. However, it is not possible at present to determine how much of the neutralization took place in the collector and how much in the atmosphere beforehand.

Ammonium concentration in precipitation at the Athens, Pa., station was three times greater than at other sites. A principal source may have been decom-

Table 3.—Composition of precipitation samples from monitoring sites

[Chemical concentrations are given in milliequivalents per liter. Number of observations used in calculation of mean and standard deviation is in parentheses. Locations are given in fig. 1]

Constituent or characteristic	Monitoring site									Cogbill Likens Study[1]
	Albany	Athens	Canton	Hinckley	Mays Point	Mineola	Rock Hill	Salamanca	Upton	
Precipitation quantity (cm/year)	103 ± 64 (147)	89 ± 50 (149)	94 ± 58 (138)	129 ± 52 (159)	91 ± 44 (155)	117 ± 61 (121)	123 ± 64 (144)	123 ± 58 (144)	123 ± 66 (146)	90 to 98
Hydrogen (measured)	.020 ± .028 (142)	.047 ± .041 (146)	.034 ± .027 (135)	.051 ± .036 (147)	.040 ± .032 (146)	.026 ± .030 (118)	.046 ± .039 (140)	.056 ± .052 (130)	.051 ± .034 (137)	.087
Hydrogen (calculated)	.017	.055	.027	.041	.038	.030	.053	.081	.050	.088
pH	4.69	4.32	4.46	4.29	4.39	4.58	4.33	4.25	4.29	4.06
Specific conductance (μmho/cm at 25° C)	36 ± 17 (147)	44 ± 22 (150)	34 ± 16 (141)	34 ± 13 (160)	38 ± 15 (156)	47 ± 35 (126)	36 ± 16 (146)	48 ± 40 (144)	38 ± 16 (146)	----
Total ions	.463 ± .252 (113)	.386 ± .234 (109)	.349 ± .227 (105)	.258 ± .095 (112)	.383 ± .214 (119)	.460 ± .237 (87)	.332 ± .228 (110)	.380 ± .279 (97)	.296 ± .108 (105)	.315
Calcium	.143 ± .095 (141)	.055 ± .058 (135)	.068 ± .065 (132)	.043 ± .035 (148)	.088 ± .060 (151)	.086 ± .071 (120)	.043 ± .040 (137)	.058 ± .085 (136)	.024 ± .019 (135)	.034
Magnesium	.021 ± .012 (141)	.014 ± .021 (136)	.025 ± .018 (132)	.012 ± .012 (148)	.022 ± .014 (151)	.045 ± .034 (120)	.018 ± .022 (138)	.015 ± .016 (136)	.016 ± .019 (135)	.008
Sodium	.031 ± .048 (141)	.021 ± .033 (136)	.019 ± .038 (132)	.010 ± .008 (148)	.023 ± .049 (151)	.058 ± .099 (120)	.016 ± .020 (138)	.030 ± .054 (137)	.650 ± .031 (134)	.005
Potassium	.006 ± .010 (141)	.007 ± .015 (136)	.007 ± .028 (132)	.003 ± .004 (148)	.005 ± .009 (151)	.004 ± .010 (120)	.020 ± .044 (138)	.008 ± .015 (137)	.003 ± .004 (134)	.002
Ammonium	.014 ± .019 (121)	.063 ± .066 (118)	.023 ± .023 (114)	.019 ± .021 (126)	.020 ± .026 (131)	.032 ± .032 (93)	.020 ± .035 (118)	.033 ± .069 (117)	.011 ± .012 (120)	.021
Sulfate	.131 ± .063 (139)	.130 ± .076 (137)	.104 ± .057 (131)	.084 ± .039 (148)	.110 ± .049 (151)	.128 ± .083 (122)	.098 ± .055 (138)	.140 ± .206 (138)	.074 ± .045 (137)	.098
Nitrate	.041 ± .029 (133)	.050 ± .062 (127)	.040 ± .035 (117)	.033 ± .025 (133)	.043 ± .030 (143)	.042 ± .035 (119)	.030 ± .025 (120)	.046 ± .062 (122)	.027 ± .017 (139)	.048
pre-1969	.037 ± .028 (38)	.009 ± .009 (27)	.015 ± .017 (32)	.012 ± .017 (24)	.015 ± .023 (33)	.015 ± .016 (37)	.009 ± .010 (23)	.015 ± .018 (26)	.011 ± .010 (38)	
post-1969	.043 ± .030 (95)	.056 ± .060 (100)	.049 ± .035 (85)	.033 ± .024 (109)	.051 ± .027 (110)	.054 ± .035 (82)	.035 ± .024 (97)	.054 ± .066 (96)	.033 ± .014 (101)	
Chloride	.036 ± .049 (140)	.026 ± .039 (136)	.017 ± .028 (131)	.012 ± .012 (148)	.013 ± .055 (151)	.065 ± .094 (121)	.027 ± .035 (137)	.025 ± .037 (138)	.054 ± .034 (137)	.012
Phosphate	.002 ± .003 (98)	.004 ± .006 (90)	.001 ± .002 (89)	.001 ± .002 (96)	.001 ± .002 (96)	.002 ± .003 (65)	.006 ± .011 (96)	.002 ± .003 (93)	.001 ± .001 (92)	----

[1] Data from Cogbill and Likens (1974)

posing animal wastes on the dairy farm where the collector is located. Although ammonia is a base, it did not cause a significant increase in pH, possibly because sulfate concentrations were high enough to neutralize most of the ammonia. In addition, oxidation of ammonium to nitrate during the month of field storage may have contributed some acid through the reaction

$$NH_4^+ + 2O_2 \rightleftharpoons NO_3^- + H_2O + 2H^+.$$

This hypothesis is supported by the observation that nitrate concentration was slightly higher at Athens than at other sites.

Potassium concentration at Rock Hill, in southeastern New York, was several times higher than at other stations. All other collectors in the network were either in open terrain or far enough from obstructions (such as trees) that the vertical angle between the collector's ground location and the top of the obstruction was less than 30°. At Rock Hill, the collector was among deciduous trees in a heavily wooded semiresidential area. Earlier studies, such as that of Madgwick and Ovington (1959), have shown that precipitation through a tree canopy becomes enriched with potassium, with a maximum enrichment in autumn and a minimum enrichment in spring. Potassium concentrations at Rock Hill in the late fall exceeded those in the early spring by more than an order of magnitude.

Interrelationship of Chemical Constituents

Linear regressions relating conductance and hydrogen concentration to concentration of selected constituents are given in table 4. Specific conductance of hydrogen ion exceeds that of other ions by a factor ranging from 5 to 8. The larger slopes (a values) in the conductance-against-total ions column (table 4) and in the conductance-against-hydrogen column represent stations at which the hydrogen ion is a major contributor to conductance. In general, these stations received less dryfall than the rest, as exemplified by the Albany station, an urban site having a large amount of dryfall and showing the lowest slope value in the conductance-against-hydrogen column.

In contrast to the conductance-against-total ions column, which indicates a statistically significant relationship at all stations, the acid-forming anions sulfate and nitrate showed a significant relationship at only four and seven stations, respectively. The only significant relationship between hydrogen and nitrate plus sulfate was at Hinckley and Upton. These stations had the lowest total ion concentrations, the smallest percent standard deviation in hydrogen concentration, and high hydrogen concentrations and are therefore the stations most likely to reflect changes in these acid-forming species. Furthermore, at all stations, the mean of the strong acid anion (sulfate plus nitrate) equivalents was at least twice the mean hydrogen-ion equivalents (table 3). The smallest difference between hydrogen and sulfate plus nitrate were at stations where the correlations were significant (Hinckley and Upton). Yet, this lack of stoichiometric balance illustrates the fact that hydrogen-ion concentration is a net result of a complex interaction among base-neutralizing cations as well as acid-forming anions. Also, as explained in the following section, ionic concentrations are themselves a function of precipitation quantity; therefore, any further statistical studies of these data should include a multivariate analysis to provide an understanding of the interrelationships of all species that potentially control the hydrogen-ion concentration.

Relationship of Chemical Concentration to Precipitation Quantity

Chemical concentration of bulk precipitation reflects contributions from both dryfall and wetfall. The proportion added in either form varies among constituents as well as among stations. If dryfall were the sole source of chemical constituents, wetfall would act as a diluent, and the concentration in bulk precipitation would decrease with increasing wetfall quantity. However, ions are also added in wetfall, so that dilution does not decrease concentration either as rapidly or as extensively as might be expected.

Both linear and hyperbolic regressions of major constituents were done to depict the relationship between chemical concentration and precipitation quantity and for use in the nonparametric time-trend analysis. Best least-squares relationships for each station are given in figures 3A-I. Where statistical significance at a level of 0.1 is not indicated, mean concentration is drawn as a horizontal line. However, even where a statistically significant relationship is not indicated, a functional relationship may still be possible.

The graphs in figure 3 indicate that predicted concentration generally decreases as precipitation quantity increases. An exception is hydrogen (fig. 4), which increases at all stations except Upton, although only two of these – Athens and Mays Point – show statistical significance ($\alpha < 0.1$). In all other respects, the combined data from all stations suggest a slight increase in hydrogen concentration as precipitation quantity increases.

As stated earlier, the concentration of hydrogen results from a complex interaction of many factors. Electroneutrality requires that if hydrogen concentration increases as precipitation quantity increases, the concentration of anions must decrease slightly less than those of the remaining cations (excluding hydrogen). Hence, visual inspection of the slope (rate of decrease) of the lines in figure 3 should indicate which ions affect

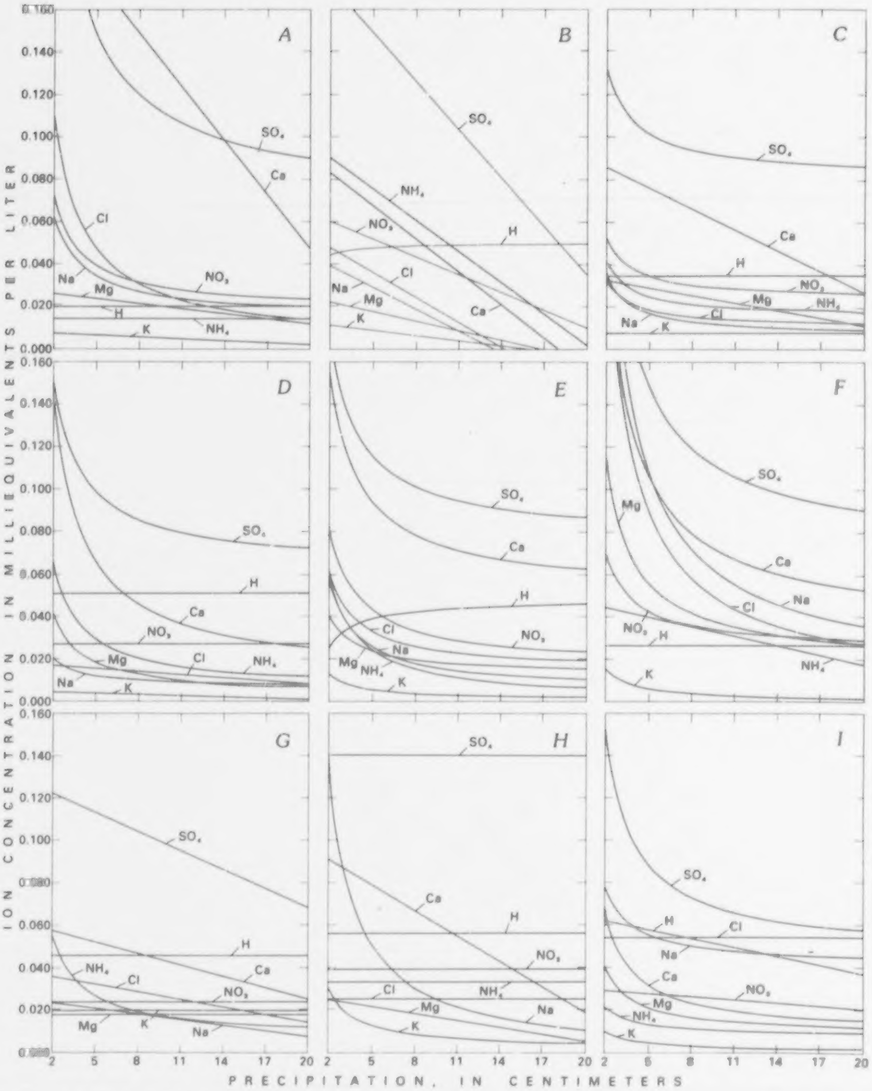

Figure 3.—Least-squares relationship between chemical concentrations and monthly precipitation quantity, 1965-78. Where no significant relationship exists at 0.1 level, mean concentration is shown as a horizontal line. *A*, Albany. *B*, Athens. *C*, Canton. *D*, Hinckley. *E*, Mays Point. *F*, Mineola. *G*, Rock Hill. *H*, Salamanca. *I*, Upton.

Table 4.—Linear regression relationships between selected chemical constituents of precipitation

[Equation is of the form $Y = aX + b$. Concentrations of total ions, hydrogen, nitrate, and sulfur are in milliequivalents per liter; specific conductance is in micromhos per centimeter at 25°C. Nitrate data are from spring 1969 through 1978. *N* is number of observations; R^2 is correlation coefficient. Locations are given in fig. 1]

Station	Specific Conductance (*Y*) vs Total ions (*X*)				Specific Conductance (*Y*) vs Hydrogen (*X*)				Hydrogen (*Y*) vs Nitrate (*X*)			
	a	*b*	*N*	$100R^2$	*a*	*b*	*N*	$100R^2$	*a*	*b*	*N*	$100R^2$
Albany	86.21	−3.48	114	[3]71.6	140.2	33.10	142	[3]5.1	0.1943	0.0139	89	[1]3.4
Athens	55.56	20.62	110	[3]47.4	228.3	32.69	145	[3]17.7	-----	-----	96	2.1
Canton	45.28	17.64	105	[3]52.7	191.88	28.18	135	[3]9.9	-----	-----	79	0.6
Hinckley	89.26	10.26	116	[3]49.8	256.97	20.83	147	[3]49.1	.3398	.0455	96	[2]4.2
Mays Point	51.06	18.96	118	[3]48.8	260.05	28.07	146	[3]30.0	-----	-----	100	.0
Mineola	49.61	16.65	93	[3]51.5	208.42	39.48	118	[2]4.1	-----	-----	77	0.3
Rock Hill	38.51	23.76	111	[3]26.3	233.33	25.90	140	[3]30.5	.5817	.0263	91	[3]12.3
Salamanca	62.55	18.44	102	[3]60.2	322.16	29.68	130	[3]20.1	-----	-----	79	0.4
Upton	313.31	−50.24	106	[3]20.2	362.72	18.94	137	[3]55.1	1.3815	.0082	91	[3]33.6

Station	Hydrogen (*Y*) vs Sulfate (*X*)				Hydrogen (*Y*) vs Nitrate + Sulfate (*X*)			
	a	*b*	*N*	$100R^2$	*a*	*b*	*N*	$100R^2$
Albany	0.663	−0.0667	134	[3]57.6	-----	-----	88	0.7
Athens	.195	.2444	129	[3]11.0	-----	-----	94	.0
Canton	----	----	124	.1	-----	-----	78	.7
Hinckley	.315	.0246	136	[3]11.4	0.4397	0.0076	95	[3]26.7
Mays Point	.128	.0360	140	[2]3.0	-----	-----	100	1.4
Mineola	----	----	112	1.3	-----	-----	77	.4
Rock Hill	.140	.0342	130	[2]3.4	-----	-----	90	1.6
Salamanca	.163	.0344	122	[3]6.4	-----	-----	80	2.0
Upton	.523	.0128	121	[3]41.1	.4303	.0094	88	[3]36.2

[1] Indicates statistical significance $\alpha < 0.10$.

[2] Indicates statistical significance $\alpha < 0.05$.

[3] Indicates statistical significance $\alpha < 0.01$.

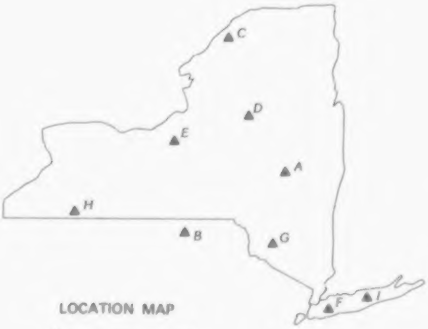

Figure 3.—Continued

Table 5.—Results of linear regression analysis for precipitation constituent against time

[Average percent slope (trend per year) is calculated by dividing the slope (a-coefficient) by the mean value in table 3. N is number of observations.

A. Precipitation quantity

[Equation is of the form $Y = aX + b$, where Y is quantity per year, in centimeters, and X is calendar year minus 1900]

Station	a	b	N	$100R^2$	Average percent slope
Albany	0.277	−11.41	147	[2]4.0	3.2
Athens	.259	−11.26	149	[3]5.5	3.5
Canton	.195	−6.24	138	[1]2.5	2.5
Hinckley	.194	−3.29	159	[2]2.9	1.8
May Point	----	----	155	1.7	--
Mineola	.392	−18.18	121	[3]5.6	4.0
Rock Hill	.295	−11.09	144	[2]4.4	2.9
Salamanca	.178	−2.66	144	[1]2.0	1.7
Upton	.185	−3.14	146	[1]2.0	1.8

B. pH

[Equation is of the form $Y = aX + b$, where Y is pH and X is calendar year minus 1900]

Station	a	b	N	$100R^2$
Albany	-----	-----	143	0.2
Athens	-----	-----	145	0.3
Canton	0.0088	4.344	135	[3]3.6
Hinckley	−.0093	4.831	148	[3]7.5
Mays Point	-----	-----	144	1.0
Mineola	.0244	4.022	118	[3]12.2
Rock Hill	.0121	4.070	141	[3]6.7
Salamanca	−.0123	5.098	130	[2]4.6
Upton	-----	-----	134	0.0

C. Sulfate-ion concentration

[Equation is of the form $Y = aX + b$, where Y is concentration, in milliequivalents per liter, and X is calendar year minus 1900]

Station	a	b	N	$100R^2$	Average percent slope
Albany	−0.0015	0.2057	134	[3]3.9	−1.0
Athens	.0009	.0900	130	[1]2.8	.7
Canton	-----	-----	124	0	--
Hinckley	-----	-----	136	1.8	--
Mays Point	-----	-----	139	.2	--
Mineola	−.0014	.1880	115	[2]3.6	−1.1
Rock Hill	-----	-----	130	0	--
Salamanca	-----	-----	121	0	--
Upton	−.0008	.1081	123	[3]7.7	−1.1

D. Nitrate-ion concentration

[Equation is of the form $Y = aX + b$, where Y is concentration, in milliequivalents per liter, and X is calendar year minus 1900]

Station	a	b	N	$100R^2$	Average Percent slope
Albany					
Total period	-----	-----	133	0.0	---
pre-1969	-----	-----	38	2.5	---
post-1969	-----	-----	95	.2	---
Athens					
Total period	0.0065	−.4248	126	[3]15.9	12.9
pre-1969	-----	-----	27	3.8	---
post-1969	.0038	−.2266	99	[3]8.8	6.7
Canton					
Total period	.0030	−.1795	117	[3]12.1	7.6
pre-1969	.0071	−.4651	32	[3]16.5	47.3
post-1969	-----	-----	85	0	---

Table 5.—Results of linear regression analysis for precipitation constituent against time—Continued

D. Nitrate-ion concentration—Continued

[Equation is of the form $Y = aX + b$, where Y is concentration, in milliequivalents per liter, and X is calendar year minus 1900]

Station	a	b	N	$100R^2$	Average Percent slope
Hinckley					
Total period	.0025	−.1525	133	[3]13.4	7.6
pre-1969	-----	-----	24	8.4	---
post-1969	-----	-----	109	1.4	---
Mays Point					
Total period	.0043	−.2634	143	[3]14.5	10.3
pre-1969	.0082	−.5378	33	[2]13.4	53.2
post-1969	-----	-----	110	1.3	---
Mineola					
Total period	.0014	−.0185	119	[3]37.7	3.8
pre-1969	-----	-----	37	.2	---
post-1969	-----	-----	82	.3	---
Rock Hill					
Total period	.0023	−.1369	120	[3]11.5	7.7
pre-1969	-----	-----	23	9.3	---
post-1969	-----	-----	97	.6	---
Salamanca					
Total period	-----	-----	122	1.8	---
pre-1969	-----	-----	26	.6	---
post-1969	-----	-----	96	1.0	---
Upton					
Total period	.0021	−.1249	139	[3]27.9	7.9
pre-1969	-----	-----	38	5.3	---
post-1969	.0007	−.0227	101	[1]2.7	2.1

[1] Indicates statistical significance $\alpha < 0.10$

[2] Indicates statistical significance $\alpha < 0.05$

[3] Indicates statistical significance $\alpha < 0.01$

the concentration of the hydrogen ion. The pattern most evident in these graphs is that as precipitation quantity increases, both sulfate and calcium decrease, but the decrease in calcium is slightly more pronounced. The samples from Athens (fig. 3*B*) are an exception, as pointed out earlier, because the anomalously high concentrations of ammonium contributed as much as did calcium to the reaction or exchange with hydrogen, resulting in neutralization of acid. The Upton samples (fig. 3*I*) were also unique in that the decrease in acid-forming anions exceeded the decrease in neutralizing cations, which caused a net decrease in hydrogen concentration with increasing precipitation. The Upton results reflect the local coastal conditions of little contribution from dust and large contributions of sodium and chloride from sea salt.

Temporal Trends

Linear Regression

The initial form of data analysis was the simple linear regression of precipitation quantity and chemistry against time. Results are given in table 5; the corresponding historical values of precipitation quantity, pH, sulfate, and nitrate, and their regression lines for each station, are given in figures 5-8.

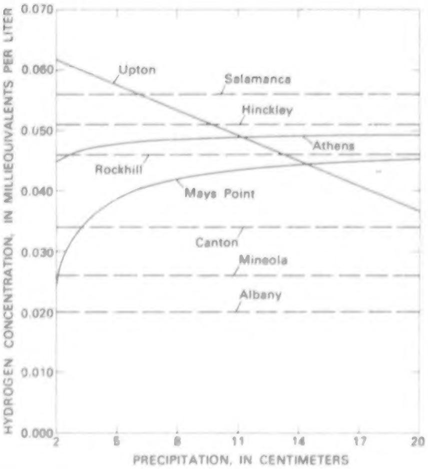

Figure 4.—Relationship between hydrogen concentration and precipitation quantity, 1965-78, at all stations. Dashed lines indicate that a relationship is statistically insignificant at $\alpha<0.1$. Where no significant relationship exists at the 0.1 level, mean concentration is shown as a horizontal (dashed) line.

A linear representation is not necessarily the form that most accurately reveals the change that actually occurs. For example, a constant rate of increase in chemical concentration would result in an exponential curve, whereas a period of rapid increase followed by gradual increase would produce an S-shaped curve. Also, minor perturbations reflecting storms or dry weather, as well as normal seasonal variations, would cause fluctuations in the data that would mask long-term trends. One effect of imposing a linear fit may be to exaggerate the predicted values representing the beginning and end of the period of record. For example, applying a linear fit to data representing a constant rate of increase in concentration with time would cause the line to fall below the data cluster at the beginning and end of the graph and above it in the middle.

Because the assumptions underlying the least-square relationships were not well satisfied by the data, the concentrations calculated from these relationships should be interpreted with caution. For example, even though the slopes of chemical concentrations plotted as a function of time may be compared among one another to discern direct relationships, hydrogen concentration is non-normally distributed and yielded many near-zero values that would have affected the slope of a linear regression, thus making trends difficult to discern. The application of linear regression analysis to hydrogen concentration would, therefore, violate the test assumptions and possibly produce an unreliable result. To obtain a more reliable analysis, a linear trend in pH, rather than hydrogen ion concentration, was assessed.

Results of the linear regression analyses suggest that nitrate increased at eight of nine stations over the sampling period (fig. 8). As mentioned previously, however, the analytical technique for nitrate changed in the spring of 1969. Although the effects of this change on accuracy and precision of the data are unknown, data before 1969 seem to be drawn from a different population than those after 1969 (fig. 8); this has also been suggested by Miller and Everett (1979). Only two of nine stations show significant trends at the 0.1 level after the spring of 1969, and two stations show trends before this time (fig. 8, table 5).

The results of the linear regression analyses suggest that sulfate decreased at three of the nine stations and increased at one (fig. 7). pH increased at only two stations and decreased at three. However, a trend in pH cannot be derived from the linear trends in concentration of sulfate and nitrate, which are the acid-forming anions.

In addition, figure 5 indicates a 2- to 3-percent average annual increase in precipitation quantity during 1965-78, although little or no increase is indicated by longer periods of record. For example, the average annual increase at Albany since 1900 has been only 0.2 percent (fig. 9). The lack of detectable change in pH at some stations and a decrease in pH, as observed at six sites in the central and western part of the State, coupled with a 2- to 3-percent average annual increase in precipitation, has resulted in an increase in loading of hydrogen ions. The relationship between concentration and precipitation quantity as noted in figures 3 and 4, coupled with the change in precipitation quantity with time (fig. 9) and possible seasonal variations in constituent concentrations, further reduce the reliability of these linear trends. The seasonal Kendall test is more robust and attempts to account for these factors in addition to lack of normality (Hirsh and others, 1982).

Nonparametric Seasonal Kendall Test

Results of the seasonal Kendall test (table 6) generally agree with those obtained from the linear regression in table 5, although magnitudes of the trends differ somewhat, and a greater number of statistically significant trends results from the seasonal Kendall test. Also, the nine-station average sulfate trend obtained from the parametric test exceeded that of the nonparametric test by 1.5 (μeq/L)/yr.

Temporal trends of constituents having common sources, such as calcium and magnesium from dustfall, are virtually identical at a given station. However, the trend for hydrogen ion, a net result of several other fac-

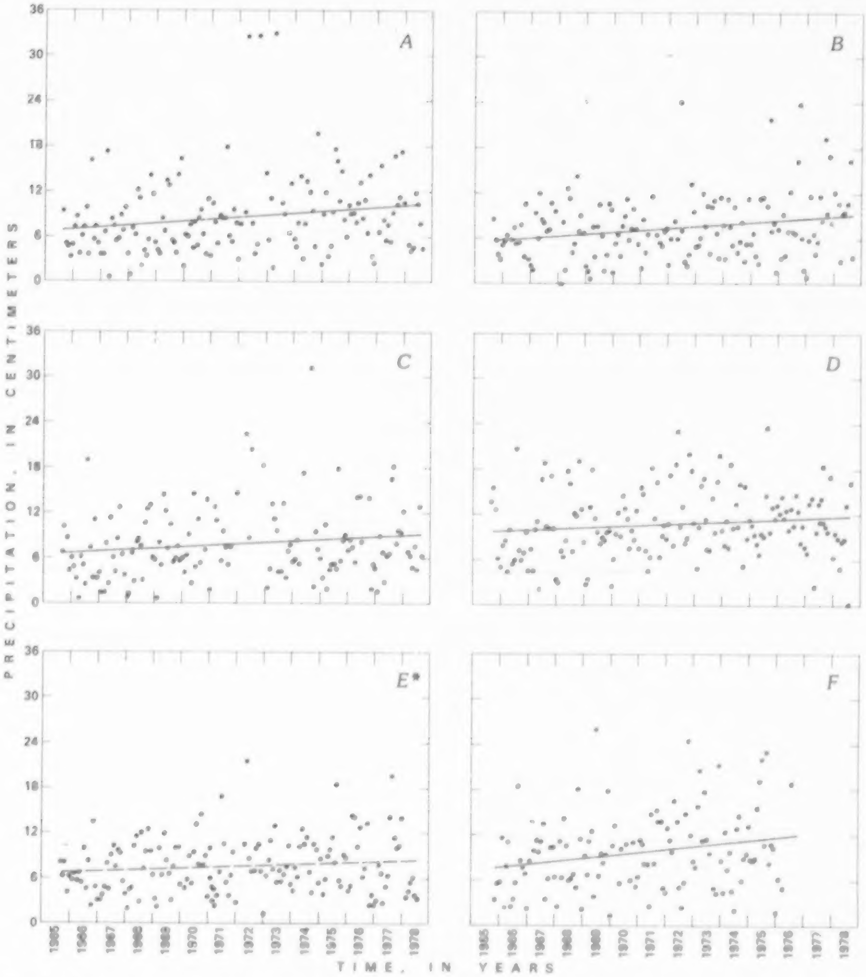

Figure 5.—Temporal trend in monthly atmospheric precipitation quantity, 1965-78, based on least-squares fit of data. Dashed line (denoted by asterisk after letter on figure) indicates trend is not statistically significant at $\alpha<0.1$. *A*, Albany. *B*, Athens. *C*, Canton. *D*, Hinckley. *E*, Mays Point. *F*, Mineola. *G*, Rock Hill. *H*, Salamanca. *I*, Upton.

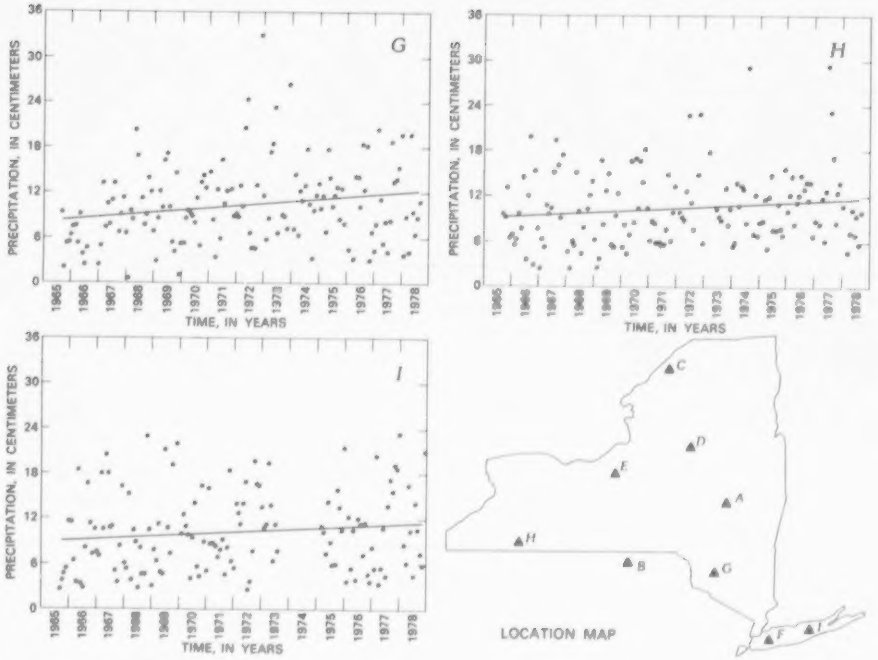

Figure 5.—Continued.

tors, cannot be predicted as readily. By a procedure analogous to Granat's (1972) estimate of hydrogen-ion concentration (table 3), hydrogen trend was calculated from the difference between anion and cation trends. Comparison of calculated hydrogen-ion trends with measured trends showed generally poor agreement. At six of the nine stations, differences exceeding (1 µeq/L)/yr were observed. At Hinckley, Mays Point, and Salamanca, a decrease in hydrogen ion was calculated, but the Kendall test results suggest an increase. At Mineola and Rock Hill, the opposite was observed. Changes in bicarbonate (alkalinity) over the period of record could explain these differences. If bicarbonate increased at Rock Hill and Mineola, correlative with the increases in base cations (calcium, sodium, magnesium, and potassium), a decrease in hydrogen would be expected. Similarly, if bicarbonate decreased at Hinckley, Mays Point, and Salamanca, an increase in hydrogen, as indicated by the Kendall test results, would be expected.

Records from three stations (Albany, Athens, and Upton) show no statistically significant trend in hydrogen-ion concentration. In contrast, Hinckley, Mays Point, and Salamanca show a statistically significant increase ranging from 3 to 6 percent, and the remaining stations (Canton, Mineola, and Rock Hill) show a comparable decrease. As a whole, these trends balance out to suggest that pH of precipitation in New York has not changed since 1965, although station-to-station comparisons reveal significant local differences.

The increase in hydrogen ion at Hinckley, Mays Point, and Salamanca would suggest a decrease in pH in the western and central part of New York, whereas the hydrogen-ion decrease at Canton, Mineola, and Rock Hill would suggest an increase in pH in the southeastern and northeastern part. One factor may be proximity to the industrialized Midwest, a major source of acid airborne emissions and a general west-to-east transport by wind. Cogbill and Likens (1974), in their central New York study, noted that pH of wetfall originating in air

Table 6.—Results of temporal-trend analysis of precipitation data based on nonparametric seasonal Kendall test
[Functional equations for *f(Q)* are based on relationships between chemical concentration and precipitation quantity displayed in figs. 3*A*-*I*, where M = mean, L = linear, and H = hyperbolic. Nitrate trends calculated for data after spring of 1969. For chemical concentrations, slope is trend, in milliequivalents per liter per year. Average percent slope is calculated as slope divided by mean in table 3.]

Station	Hydrogen			Calcium			Magnesium			Sodium			Potassium		
	Slope	Average percent slope	*f(Q)*	Slope	Average percent slope	*f(Q)*	Slope	Average percent slope	*f(Q)*	Slope	Average percent slope	*f(Q)*	Slope	Average percent slope	*f(Q)*
Albany	----	----	--	-0.0045	[1]-3.2	L	----	----	--	----	----	--	----	----	--
Athens	----	----	--	.0016	[3]2.9	L	0.0007	[3]5.0	L	----	----	--	0.0002	[3]2.9	L
Canton	0.0011	[1]-3.2	M	.0015	[3]2.2	L	.0012	[3]4.8	L	----	----	--	----	----	--
Hinckley	.0018	[3]3.5	M	----	----	--	----	----	--	-.0003	[1]-3.0	H	----	----	--
Mays Point	.0015	[3]3.8	H	----	----	--	----	----	--	----	----	--	----	----	--
Mineola	-.0019	[1]-7.3	M	.0022	[3]2.6	H	.0022	[3]4.9	H	----	----	--	----	----	--
Rock Hill	-.0020	[1]-4.3	M	.0012	[3]2.8	L	.0008	[3]1.9	M	----	----	--	.0004	[3]2.0	M
Salamanca	.0035	[3]6.3	M	----	----	--	----	----	--	-.0013	[2]-8.9	H	----	----	--
Upton	----	----	--	----	----	--	----	----	--	----	----	--	----	----	--

[1] Indicates statistical significance α0.10.
[2] Indicates statistical significance α0.05.
[3] Indicates statistical significance α0.01.

masses with a western component was lower by 0.25 units than wetfall originating in air masses with a southern or northern component. The Canton (northeastern) station might be less likely to receive storms with a western component than would Salamanca, Mays Point, or Hinckley. This may be only a partial explanation, however. For example, the sum of calcium, magnesium, and sodium in bulk samples decreased at stations where hydrogen-ion concentrations increased, and their sum increased where hydrogen decreased. Thus, geographic differences in hydrogen-ion trends may be partly attributed to local trends in base-neutralizing dryfall.

Nitrate concentrations increased at only three of the nine stations. Two of these stations, Hinckley and Upton, as mentioned previously, have the lowest total ion concentrations, and are, therefore, the most sensitive to changes in precipitation chemistry. The increase in nitrate detected from the bulk precipitation data at these stations, however, is insufficient to suggest a regional nitrate increase.

Trends in sulfate concentrations during the period studied are definable; sulfate decreased 1-4 percent per year at seven of the nine stations These trends compare favorably with those derived by Cogbill and Likens (1974) from a combination of measured and calculated data. Although results from that study indicate that the amount of acid-forming nitrate ion increased from 22 percent of the total acid-forming anions in 1955 to 30 percent in 1973, the pH in central New York remained the same, chloride increased from 0 to 5 percent, and sulfate decreased from 78 to 65 percent during the same interval.

Although the ratio of nitrate to nitrate plus sulfate in the Geological Survey network exceeded that in Cogbill and Likens' (1974) study by several percent, this difference may not be important because it may result from differences in method of collection (wetfall versus bulk) and chemical and biological alteration during the 1-month storage period in the field.

The data obtained suggest a slight decrease in sulfate concentration within the State. A reduction in the burning of wood and coal and a corresponding increase in the use of cleaner petroleum should have produced a decrease in sulfate, but this trend has been counterbalanced by an increased consumption of fuel, a decrease in the release of coal ash (a neutralizing component), and possibly the removal of all but the gaseous acid component by scrubbers on tall smokestacks. The data in table 6 also indicate an increase in ammonium concentrations. Whether the ammonium increase results from human activity such as use of anhydrous ammonia and urea fertilizers or from natural biological processes is not known; its subsequent oxidation at Athens may partly account for the increasing trend in nitrate there.

Surface Water

Surface water is more difficult to interpret in terms of chemical character than precipitation because it is influenced by many more factors. Where the terrain is unreactive to water, chemical composition of the water will be similar to that of atmospheric deposition, but where the rocks are reactive, the water will be affected by a complex series of reaction equilibria and kinetics. Urbanization may further complicate the chemical composition of surface water by its contributions of urban runoff, industrial waste, sediment from construction, and sewage; also, agriculture may affect the chemical composition of surface waters by increasing the weathering rate of soils, contributing animal wastes, and adding soluble chemical components from fertilizers.

Table 6.—Continued

Ammonium			Nitrate			Sulfate			Chloride			Total ions		
Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)
----	----	--	----	----	--	-0.005[3]	[3]-3.4	H	----	----	--	----	----	--
0.0087	[3]10.6	L	0.0044	[3]8.7	H	.0003	[3]2.5	L	0.0011	[3]4.3	L	0.0002	[3]5.1	L
.0008	[3]3.5	H	----	----	--	----	----	--	----	----	--	.0007	[3]2.5	H
.0012	[3]8.3	H	.0017	[3]5.0	H	-.0015	[3]-1.8	H	----	----	--	----	----	--
.0010	[3]3.0	H	----	----	--	-.0018	[3]-1.6	H	----	----	--	.0006	[3]1.8	H
.0033	[3]10.3	L	----	----	--	-.0032	[3]-4.0	H	----	----	--	.0008	[3]1.7	L
.0009	[3]6.5	H	----	----	--	----	----	--	.0007	[3]2.6	L	.0001	[3]2.8	L
----	----	--	----	----	--	-.0021	[3]-1.5	H	----	----	--	----	----	--
.0003	[3]2.7	H	.0004	[3]1.3	L	-.0026	[3]-3.3	H	----	----	--	----	----	--

[1] Indicates statistical significance ≤0.10.

[2] Indicates statistical significance ≤0.05.

[3] Indicates statistical significance ≤0.01.

Chemical Composition

Urbanization and agriculture both have major effects on chemical composition of streams, as evidenced by a comparison of the mean concentrations of chemical constituents (table 7) of Buffalo Creek basin (the most urbanized basin studied) and Black Creek basin (an agricultural basin) with those of the least disturbed basins—the East Branch of the Sacandaga River and Esopus Creek (fig. 1; table 2). Total ion concentration of Buffalo Creek and Black Creek was 7.50 meq/L and 21.71 meq/L, respectively, which is 8 to more than 20 times greater than concentrations in the undisturbed streams.

Because only one basin, Buffalo Creek, has a significant percentage of urbanization (table 2), it was difficult to compare the effect of agriculture with the effect of urbanization, but a general pattern of increasing total ion concentration with increasing percentage of agricultural land use is evident. A graph of total ion concentration (meq/L) against specific conductance (fig. 10) depicts the effects of agriculture on surface-water quality. The numbers next to the data points in figure 10 correspond to the station numbers listed in table 2, and, as the distribution of data indicates, total ion concentration and specific conductance generally increase with percentage of agricultural land use. Small exceptions to this trend are apparent in the intermediate percentage range, represented in figure 10 by the drainage basins of Gridley Creek (4), Fivemile Creek (5), Conewango Creek (6), and Buffalo Creek (7), which are 47, 39, 48, and 47 percent agricultural, respectively. Slight deviations from the general trend at these stations suggest that the type and degree of agriculture influences the general effect on chemical composition of surface water within a basin. Although Black Creek basin (7) has the same percentage of agricultural land use as Gridley Creek (4) and Conewango Creek (6) basins, the higher mean total ion concentration in Black Creek (table 7) was attributed to the higher percentage of urban land use (table 2).

From these observations, it may be inferred that the geologic character of a basin is less important than land use in determining the overall chemical composition of surface waters. The major anions in surface waters, in order of decreasing concentration, typically were bicarbonate, sulfate, and chloride. The exception was the East Branch of Sacandaga River, in an Adirondack region underlain by resistant bedrock (fig. 1), where the dominant anion was sulfate followed by bicarbonate (table 7). Mean pH of this river was 6.8, significantly less than that of the other streams studied. The low bicarbonate and high sulfate concentrations of precipitation at an adjacent site (Hinckley, fig. 1, table 3) suggest a similarity between precipitation quality and surface-water chemistry in this region.

The highest observed nitrate concentrations of surface water were in Buffalo Creek, the most urbanized basin, where mean nitrate concentration was more than an order of magnitude higher than in Black Creek, the most agricultural basin. The high nitrate concentrations in Buffalo Creek are attributed to sewage treatment and disposal. Nitrate concentrations at the remaining seven stream stations were comparable to, or slightly lower than, those in bulk monthly precipitation samples from nearby stations.

Relationship Between Chemical Composition and Discharge

Linear, hyperbolic, and general hyperbolic relationships between chemical concentration and discharge of surface water are listed by site and constituent in table 8; also given are β values (a constant related to

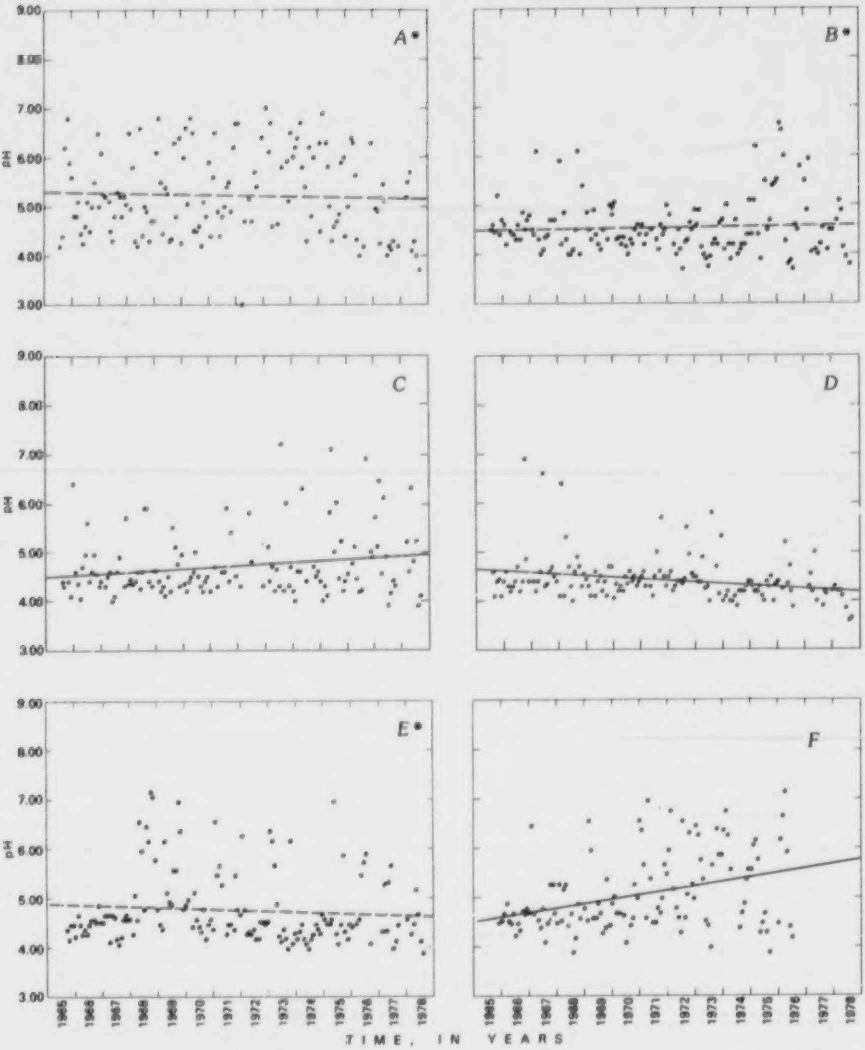

Figure 6.—Temporal trend in pH of atmospheric precipitation, 1965-78, based on least-squares fit of data. Dashed line (denoted by asterisk after letter on figure) indicates trend is not statistically significant at $\alpha<0.1$. *A*, Albany. *B*, Athens. *C*, Canton. *D*, Hinckley. *E*, Mays Point. *F*, Mineola. *G*, Rock Hill. *H*, Salamanca. *I*, Upton.

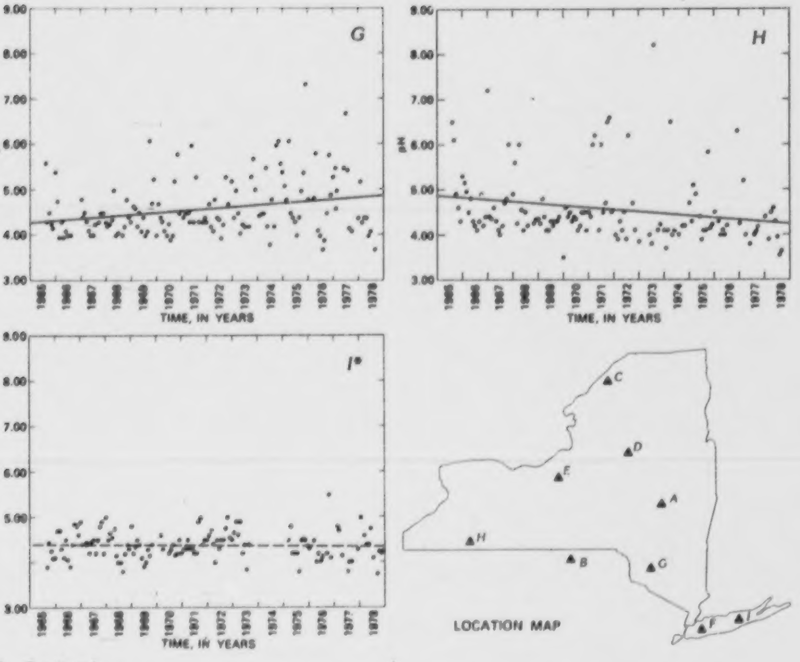

Figure 6.—Continued.

residence time of water) for the general hyperbolic relationship and the R^2 value with the corresponding significance level. The relationship of concentration to discharge was determined through the linear, hyperbolic, and general hyperbolic equations (eqs 1, 2, 3), with discharge treated in units of cubic meters per day per square kilometer $[(m^3/d)/km^2]$ to facilitate comparison with results from a similar study of watersheds in the Hubbard Brook Experimental Forest, N.H. (Johnson and others, 1969). The general hyperbolic equation (eq 3), which was devised to incorporate the mixing of ground water and surface water (Johnson and others, 1969), produced significantly better results than did the simpler linear or hyperbolic relationships (eqs 1, 2). Of the 81 possible relationships of concentration to discharge (nine constituents at each of nine stations), 61 were general hyperbolic, 4 were linear, 2 were hyperbolic, and 14 showed no significant pattern.

The β term in the general hyperbolic equation (eq 3) is defined by the limit, as stream discharge approaches zero, of the residence time of water in a basin divided by the volume of water per unit area and may be regarded as a constant related to the residence time of water in a basin. Streams draining the glaciated sedimentary strata of western and central New York generally have a relatively high ground-water storage potential, especially those in areas of low relief adjacent to the Great Lakes, and therefore are likely to have much lower β values than do streams draining the Adirondack area, which respond rapidly to precipitation as a result of the high relief, impermeable bedrock, and low storage capacity. (See β values in table 8.)

The mean exponent (for all constituents) in the term for the East Branch of the Sacandaga River, in the center of the Adirondacks, was −3.0, which is equal to published values for watersheds in the geologically

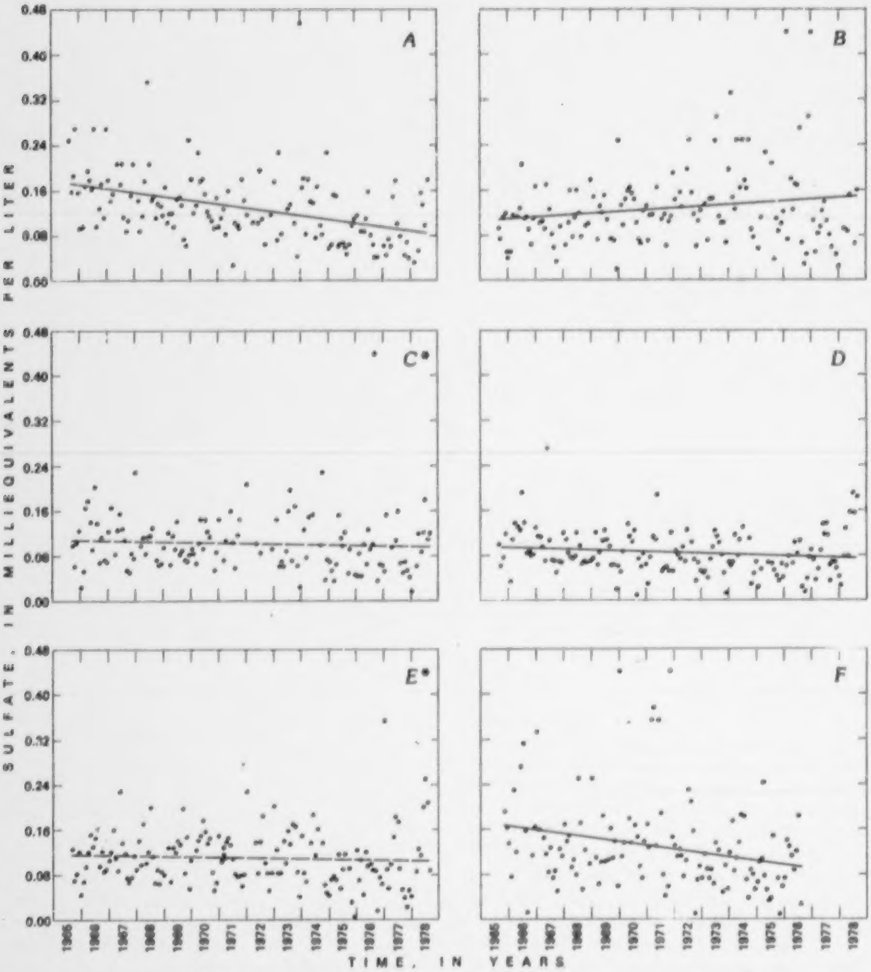

Figure 7.—Temporal trend in sulfate concentration of atmospheric precipitation, 1965–78, based on least-squares fit of data. Dashed line (denoted by asterisk after letter on figure) indicates trend is not statistically significant at $\alpha<0.1$. *A*, Albany. *B*, Athens. *C*, Canton. *D*, Hinckley. *E*, Mays Point. *F*, Mineola. *G*, Rock Hill. *H*, Salamanca. *I*, Upton.

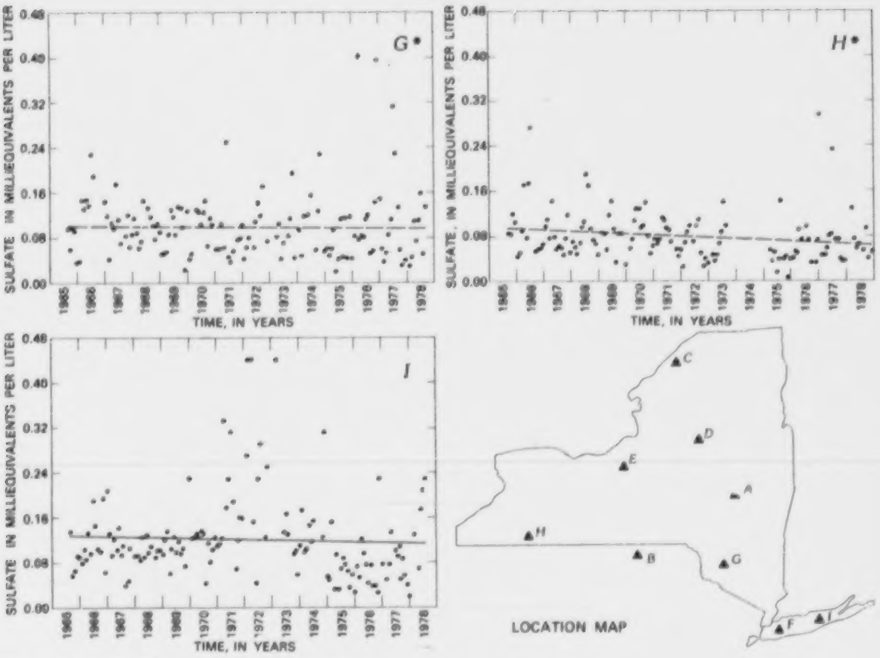

Figure 7.—Continued

similar terrain of the Hubbard Brook Experimental Forest (Johnson and others, 1969). The lowest β values, $<10^{-4.9}$, were obtained from Buffalo Creek and Fivemile Creek in the Ontario plain, which contains glaciated sedimentary rocks and has low relief. The low β value of these basins is hypothesized to result from the large volume of water per unit area at low flow. (Low relief results in low ground-water gradients.)

The intercept term (mean concentration) in the hyperbolic equation represents the predicted concentration of a constituent as discharge approaches infinity. At high discharge, the ground-water contribution to surface-water bodies is relatively small, so that the chemical signature of surface waters will mainly reflect contributions from interactions with surface sources such as vegetation, salts, and sorption-ion exchange reactions with surficial materials. The most accurate results produced by the general hyperbolic equation were those correlating discharge with total ion concentration and specific conductance (table 8). (The accuracy of results for these two factors reflects the relationship between them; see fig. 10.)

The basins that showed the closest agreement between intercept values (concentration) derived from the general hyperbolic equation (table 8) and the mean values of total concentration and specific conductance determined from bulk monthly precipitation samples at inland sites (table 3) were those that are predominantly forested (table 2). The agricultural basins had higher intercept values than did mean monthly bulk-precipitation concentrations, which indicates significant contributions of solutes from the soils.

The most urbanized basin, Buffalo Creek, probably received many components from urban runoff; yet despite the multiplicity of sources, the general hyperbolic equation provided a close fit to the relationship between discharge and chemical concentrations. However, the large negative intercept value suggests that the close fit may be fortuitous.

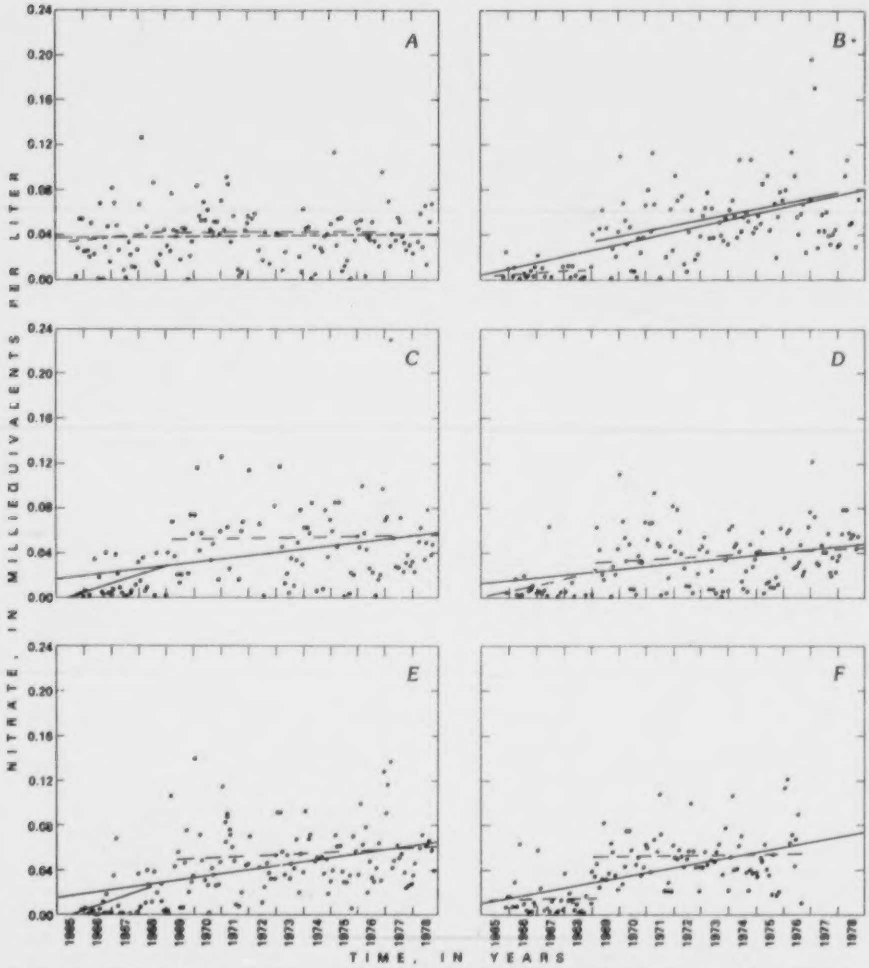

Figure 8.—Temporal trend in nitrate concentration of atmospheric precipitation, 1965-78, based on least-squares fit of data. Short lines represent period before or after spring 1969. Dashed line indicates trend is not statistically significant at $\alpha < 0.1$. *A*, Albany. *B*, Athens. *C*, Canton. *D*, Hinckley. *E*, Mays Point. *F*, Mineola. *G*, Rock Hill. *H*, Salamanca. *I*, Upton.

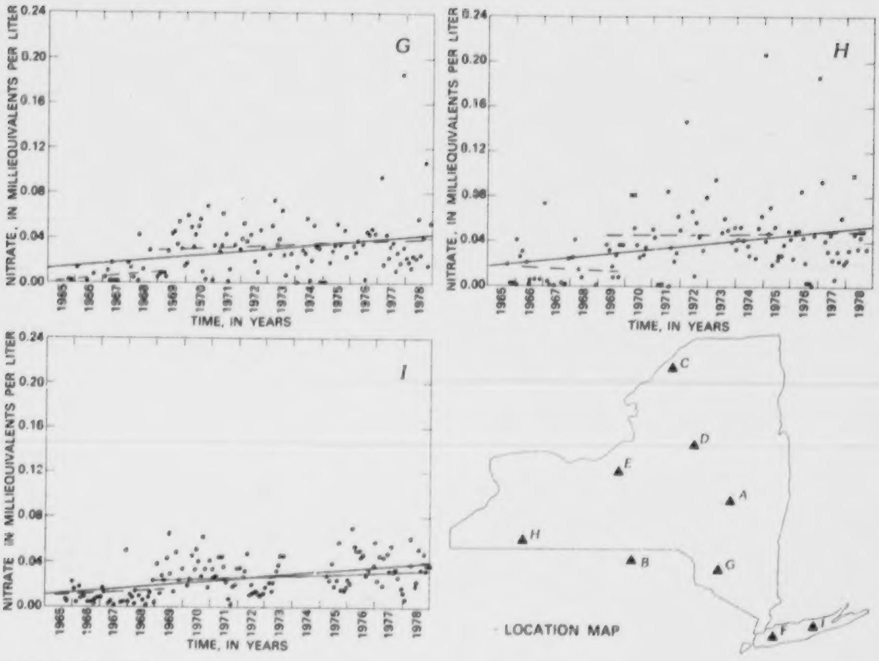

Figure 8.—Continued

A direct relationship between hydrogen-ion concentration and discharge was indicated at all sites. This relationship (table 8) reflects, in part, the extremely small interaction of the highly acidic, dilute water held in the snowpack with the soils and rocks during the spring snowmelt.

In summary, chemical trends in surface waters are affected by both urbanization and agriculture. Urbanization alters chemical-transport rates and contributes pollutants; agricultural practices increase the chemical yield of basins by exposing fresh mineral faces and increasing sedimentation and also by adding the soluble components of fertilizers and animal wastes. However, carbonate minerals in soils and (or) bedrock mask changes in the pH of runoff through their large buffering capacity and rapid reaction rate. Thus, the only streams in which pH might show a response to temporal changes in precipitation quality are in undisturbed basins in areas having unreactive rocks and soils.

Temporal Trends

Many streams showed trends in concentration of chloride and sulfate. Five streams show a statistically significant trend in chloride concentration at the 0.1 level (table 9). These trends indicate that chloride concentration has increased an average of 2 to 7 percent per year. In addition, results of the seasonal Kendall test suggest that sulfate concentrations have decreased by an average of 1 to 4 percent Statewide in seven of the nine streams. Trends in sulfate concentrations were not detected at Gridley Creek and Oquaga Creek, possibly reflecting the shorter period of record for these streams than for the other streams (table 2). This decrease in sulfate concentration in streams is similar to that observed for precipitation (table 6) and may, therefore, reflect a decrease in sulfate from atmospheric deposition. A decrease in sulfate in headwater streams in Pennslyvania has also been observed (Ritter and Brown, 1981).

Of the nine basins studied, only the East Branch of the Sacandaga River is characterized by crystalline bedrock and little disturbance; the rest are underlain by sedimentary rocks containing carbonate minerals and have higher percentages of urbanization and agriculture. Chemical analyses of the East Branch of the Sacandaga River (table 9) indicate significant trends in concentration of nitrate, sulfate, chloride, total ions, and alkalinity but no discernible trends in hydrogen-ion concentration. One explanation may be that trends in the two acid-forming anions (nitrate and sulfate) offset each other; nitrate increased 0.0040 (meq/L)/yr, whereas sulfate decreased 0.0041 (meq/L)/yr. These values agree with those of a similar study on the East Branch of the Sacandaga by Schofield (written commun., 1976).

Bicarbonate ion is produced from mineral weathering in soils. The higher concentration of sulfate than bicarbonate (table 7) in samples from the East Branch of Sacandaga basin suggest little interaction between precipitation and soils. Furthermore, if the decrease of sulfate in precipitation of 0.002 (meq/L)/yr is adjusted for enrichment caused by evapotranspiration, the adjusted value nearly matches the observed decreasing trend of 0.004 (meq/L)/yr (table 6). The increased hydrogen-ion loadings in precipitation with time and the small interaction of water with the soil suggest that the basin water has a low capacity to neutralize acid. This observation is supported by the stream's decrease in alkalinity of 0.083 (meq/L)/yr since 1965.

In general, hydrogen-ion concentration of surface water is a function of many geochemical and biochemical reactions, which makes it virtually impossible to relate trends to any simple cause. For example, hydrogen-ion concentration of Fivemile Creek (fig. 1) has increased 0.026×10^{-3} (meq/L)/yr since 1965, although nitrate and sulfate have decreased 5.4×10^{-3} and 10×10^{-3} (meq/L)/yr, respectively. Furthermore, alkalinity has actually increased despite the increase in hydrogen-ion concentration. Results from other basins are similarly complex, and trends are difficult to interpret, not only in terms of hydrogen ion but also in other constituents. Several trends are discernible from the data in table 9; however, it is beyond the scope of this study to evaluate their possible causes.

CONSIDERATIONS FOR FUTURE STUDIES

In 1964, when sampling of atmospheric deposition began, the use of bulk precipitation as a measure of atmospheric input was an accepted practice, and some of the problems associated with this practice were not widely recognized. For example, dry fallout when collected by a funnel loses a large fraction of the fine suspended particulates upon impact. Furthermore, much of the material settling into the collector may be locally derived, which would mask the effects of regional changes. It would be desirable to continue the stations for at least two more years with bulk collectors beside collectors that separate wetfall from dryfall. The data so obtained should help to identify the differences between dryfall and wetfall and help differentiate between local and regional influences in bulk-sample data collected in the past. Analysis of the soluble dryfall material should indicate the extent to which dryfall affects chemistry of bulk precipitation samples. Comparison of nutrients in wetfall samples with leachable nutrients from dryfall and with nutrients in refrigerated bulk samples collected monthly would establish the extent of nutrient change during storage. Such information would permit closer evaluation of the nutrient information given in this report.

The discussion of trends in stream chemistry describes the major factors that inhibit evaluation of the effect of precipitation chemistry on stream chemistry. However, it should be possible to select a few small streams and lakes in the Adirondack and Catskill Mountains and monitor precipitation and stream chemistry over the next 10 to 20 years; this could provide an adequate long-term record for assessing temporal trends.

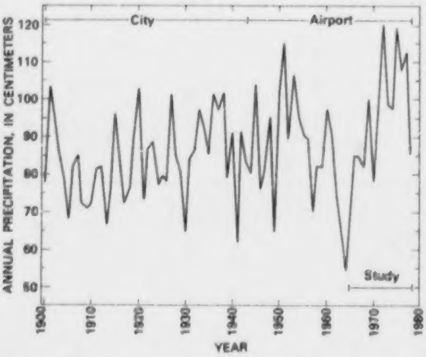

Figure 9.—Annual precipitation quantity from 1900-80 at Albany, N.Y.

Table 7.—Mean composition of surface water at sampling sites in New York

[Values are in milliequivalents per liter except as indicated; number of observations is in parentheses. Site locations are given in fig. 1]

Constituent or characteristic	East Branch Sacandaga River at Griffin	Esopus Creek at Shandaken	Oquaga Creek near Sanford	Cridley Creek above East Virgil	Fivemile Creek near Kanona	Conewango Creek at Waterboro	Buffalo Creek at Gardenville	Black Creek at Churchville	Deer Creek at Brasher Iron Works
Discharge (m³/s)	6.91 ± 13.74 (115)	3.80 ± 4.06 (154)	0.17 ± 0.19 (67)	0.60 ± 0.88 (55)	2.24 ± 5.04 (109)	15.79 ± 17.21 (120)	5.53 ± 8.90 (105)	3.85 ± 5.39 (116)	8.25 ± 11.55 (116)
Normalized discharge [(m³/d)/km²]	2,024. ± 4,024. (115)	2,135. ± 2,275. (154)	1,182. ± 1,356. (67)	1,929. ± 2,828. (55)	1,117. ± 2,515. (109)	1,802. ± 1,964. (120)	1,281. ± 2,061. (105)	1,043. ± 1,461. (116)	1,454. ± 2,037. (116)
Hydrogen (measured)	.000206 ± .000184 (115)	.000269 ± .000465 (154)	.000321 ± .000639 (67)	.000059 ± .000058 (55)	.000026 ± .000027 (109)	.000047 ± .000029 (120)	.000017 ± .000012 (107)	.000014 ± .000009 (116)	.000046 ± .000032 (117)
pH	6.69	6.57	6.49	7.23	7.59	7.33	7.77	7.85	7.34
Specific conductance (micromho/cm at 25°C)	47.1 ± 8.0 (115)	53.7 ± 10.1 (154)	67.8 ± 20.0 (67)	197. ± 74. (55)	262. ± 76. (109)	231. ± 68. (120)	377. ± 68. (107)	1021. ± 252. (116)	132. ± 26. (117)
Alkalinity (mg/L as CaCO₃)	8.30 ± 3.23 (115)	11.08 ± 3.76 (151)	17.71 ± 10.27 (55)	61.07 ± 31.87 (55)	77.32 ± 32.32 (109)	80.02 ± 29.23 (120)	112.57 ± 23.26 (107)	196.12 ± 39.98 (116)	49.03 ± 10.46 (117)
Total ions	.854 ± .174 (65)	.944 ± .192 (133)	1.270 ± .403 (32)	3.636 ± 1.556 (54)	5.040 ± 1.702 (72)	4.471 ± 1.430 (86)	7.50 ± 1.38 (72)	21.71 ± 5.45 (69)	2.71 ± .51 (65)
Calcium	.267 ± .044 (101)	.270 ± .059 (152)	.361 ± .143 (39)	1.224 ± .543 (55)	1.653 ± .527 (95)	1.611 ± 0.505 (106)	2.449 ± .439 (93)	7.731 ± 2.169 (100)	.838 ± .158 (102)
Magnesium	.093 ± .050 (101)	.098 ± .020 (152)	.143 ± .058 (39)	.398 ± .177 (55)	.622 ± .223 (95)	.468 ± .202 (106)	.829 ± .246 (93)	2.798 ± .880 (100)	.424 ± .111 (102)
Sodium	.075 ± .022 (66)	.089 ± .030 (151)	.103 ± .033 (39)	.236 ± .083 (54)	.284 ± .094 (72)	.166 ± .057 (86)	.498 ± .199 (74)	.961 ± .280 (70)	.100 ± .031 (67)
Potassium	.007 ± .004 (66)	.009 ± .004 (152)	.015 ± .005 (39)	.024 ± .006 (55)	.038 ± .010 (72)	.035 ± .011 (86)	.063 ± .019 (74)	.074 ± .019 (69)	.023 ± .010 (67)
Ammonium	.007 ± .006 (47)	.004 ± .004 (4)	.002 ± .002 (25)	---- (0)	.008 ± .005 (47)	.007 ± .007 (51)	.007 ± .007 (46)	.009 ± .012 (46)	.010 ± .010 (46)
Sulfate	.207 ± .037 (108)	.163 ± .032 (152)	.188 ± .038 (49)	.285 ± .048 (55)	.633 ± .154 (105)	.460 ± .107 (111)	.968 ± .232 (106)	5.651 ± 2.673 (107)	.281 ± .088 (107)
Nitrate	.023 ± .016 (47)	.017 ± .011 (95)	.011 ± .007 (52)	.038 ± .012 (54)	.052 ± .030 (47)	.047 ± .017 (52)	.551 ± .211 (47)	.077 ± .049 (46)	.020 ± .014 (46)
Chloride	.057 ± .032 (113)	.090 ± .042 (152)	.076 ± .032 (54)	.276 ± .138 (55)	.329 ± .112 (109)	.174 ± .058 (117)	.044 ± .035 (47)	1.301 ± .275 (112)	.064 ± .032 (114)
Bicarbonate	.166 ± .065 (115)	.222 ± .078 (136)	.357 ± .205 (52)	1.219 ± .638 (55)	1.525 ± .634 (109)	1.599 ± .584 (120)	2.241 ± .461 (107)	3.915 ± .801 (116)	.098 ± .209 (117)
Phosphate	.001 ± .001 (83)	.001 ± .001 (132)	.001 ± .001 (22)	---- (1)	.006 ± .012 (82)	.004 ± .003 (84)	.003 ± .004 (82)	.004 ± .003 (82)	.006 ± .004 (82)

Table 8.—Results of linear, hyperbolic, and general hyperbolic relationships between chemical concentration and discharge of surface water at all stations

[All relationships are in the form $C_i = A \cdot f(Q) + b$, where Y is concentration and $f(Q)$ is equal to X, linear; $1/X$, hyperbolic; and $1/(1 + \beta \cdot X)$, general hyperbolic. R^2 is coefficient of determination. Number of observations is in parentheses. Locations are given in fig. 1]

$f(Q)$	Hydrogen				Calcium				Ammonium			
	a	b	β	$100R^2$	a	b	β	$100R^2$	a	b	β	$100R^2$
East Branch Sacandaga River at Griffin:												
Linear	21.2×10^{-9}	0.163	(115)	^{1}21.7	-0.53×10^{-6}	0.28	(101)	^{1}28.1	0.6×10^{-6}	0.0057	(47)	3.3
Hyperbolic	-21.64	.252		^{1}10.3	9.28	.25		^{1}37.7	.302	.0060		1.0
General hyperbolic	-7.4×10^{-6}	8.6×10^{-6}	$10^{-4.0}$	^{1}32.0	.16	.22	$10^{-3.5}$	^{1}61.4	$-.1844$	.1900	$10^{-3.5}$	3.1
Esopus Creek at Shandaken:												
Linear	14.2×10^{-9}	.240	(152)	.5	-1.3×10^{-6}	.30	(151)	^{1}26.9	----	----	----	----
Hyperbolic	-27.26	.318		2.0	14.69	.24		^{1}37.9	----	----	----	----
General hyperbolic	-3.8×10^{-6}	3.7×10^{-6}	$10^{-3.5}$	^{1}2.9	.18	.19	$10^{-3.0}$	^{1}52.5	----	----	----	----
Oquaga Creek near North Sanford:												
Linear	3.9×10^{-9}	.317	(67)	0	-6.8×10^{-6}	.44	(39)	^{1}41.2	$-.0 \times 10^{-6}$	.0013	(35)	.0
Hyperbolic	1.00	.314		0	9.64	.23		^{1}57.7	$-.157$	.0017		2.9
General hyperbolic	-2.7×10^{-6}	3.8×10^{-6}	$10^{-3.0}$	1.2	.40	.20	$10^{-3.5}$	^{1}65.7	.066	$-.064$	$10^{-3.5}$	.9
Gridley Creek above East Virgil:												
Linear	4.4×10^{-9}	.051	(55)	4.5	-11.8×10^{-6}	1.45	(55)	^{1}37.5	----	----	----	----
Hyperbolic	-6.71	.073		^{1}6.5	218.65	.78		^{1}78.6	----	----	----	----
General hyperbolic	$-.85 \times 10^{-6}$	1.2×10^{-6}	$10^{-3.5}$	^{1}9.4	2.46	.47	$10^{-3.5}$	^{1}93.1	----	----	----	----
Fivemile Creek near Kanona:												
Linear	8.3×10^{-9}	.016	(109)	^{1}59.3	-11.42×10^{-6}	1.79	(95)	^{1}33.7	$.6 \times 10^{-6}$	.0066	(47)	^{1}17.7
Hyperbolic	$-.70$	.031		^{1}10.2	23.22	1.47		^{1}31.9	$-.012$	.0076		.1
General hyperbolic	-5.5×10^{-6}	5.7×10^{-6}	$10^{-3.5}$	^{1}60.1	1.74	.72	$10^{-3.5}$	^{1}86.1	$-.044$	.051	$10^{-3.5}$	^{1}17.6
Conewango Creek at Waterboro:												
Linear	8.5×10^{-9}	.032	(120)	^{1}13.2	-19.93×10^{-6}	1.98	(106)	^{1}64.8	1.5×10^{-6}	.0051	(51)	^{1}10.9
Hyperbolic	-6.41	.058		^{1}17.1	221.85	1.23		^{1}63.0	$-.317$	.0080		.9
General hyperbolic	-9.1×10^{-6}	9.4×10^{-6}	$10^{-4.0}$	^{1}33.2	1.97	.64	$10^{-4.0}$	^{1}84.9	$-.035$	.060	$10^{-4.0}$	^{1}11.1
Buffalo Creek at Gardenville:												
Linear	2.9×10^{-9}	.013	(105)	^{1}22.8	-11.40×10^{-6}	2.57	(91)	^{1}14.1	1.5×10^{-6}	.0045	(46)	^{1}35.7
Hyperbolic	$-.54$	.019		^{1}3.3	-10.34	2.48		1.0	$-.248$	.0076		1.5
General hyperbolic	-9.4×10^{-6}	9.5×10^{-6}	$10^{-3.5}$	^{1}22.7	11.9	9.37	$10^{-3.0}$	^{1}13.9	$-.48$	.49	$10^{-3.5}$	^{1}35.6
Black Creek at Churchville:												
Linear	$.9 \times 10^{-9}$	.013	(116)	1.9	-106.68×10^{-6}	8.81	(100)	^{1}52.3	$-.5 \times 10^{-6}$	.010	(46)	.8
Hyperbolic	$-.04$	.014		.4	60.91	7.37		^{1}15.1	.426	.0080		1.9
General hyperbolic	$-.14 \times 10^{-6}$	$.27 \times 10^{-6}$	$10^{-4.0}$	2.1	7.38	3.00	$10^{-3.0}$	^{1}69.6	.0095	.0058	$10^{-3.5}$	4.4
Deer River at Brasher Iron Works:												
Linear	2.0×10^{-9}	.043	(115)	1.3	-2.03×10^{-6}	.87	(100)	^{1}7.8	$-.1 \times 10^{-6}$	.011	(46)	.0
Hyperbolic	-2.69	.090		^{1}3.1	10.47	.82		.5	$-.144$	.011		.2
General hyperbolic	$-.37 \times 10^{-6}$	$.65 \times 10^{-6}$	$10^{-3.0}$	^{1}4.3	.45	.43	$10^{-4.0}$	^{1}9.4	.0054	.0077	$10^{-3.0}$	1.4

Table 8.—Results of linear, hyperbolic, and general hyperbolic relationships between chemical concentration and discharge of surface water at all stations—Continued

f(Q)	Nitrate				Sulfate				Chloride			
	a	b	β	100R²	a	b	β	100R²	a	b	β	100R²
East Branch Sacandaga River at Griffin:												
Linear	3.3 × 10^{-6}	.017	(47)	16.2	−1.6 × 10^{-6}	0.21	(108)	3.3	−2.1 × 10^{-6}	0.062	(112)	7.0
Hyperbolic	−3.68	.029		22.7	−2.22	.21		2.8	3.91	.049		11.1
General hyperbolic	−.048	.037	10[illegible]	31.4	.047	.17	10[illegible]	3.4	.064	.024	10[illegible]	70.8
Esopus Creek at Shandaken:												
Linear	3.2 × 10^{-6}	.011	(95)	25.3	.8 × 10^{-6}	.16	(151)	.3	−6.2 × 10^{-6}	.10	(150)	11.0
Hyperbolic	−1.77	.020		11.7	−.95	.16		.4	7.69	.078		19.0
General hyperbolic	−.050	.060	10[illegible]	25.5	−.25	.41	10[illegible]	.3	.099	.065	10[illegible]	23.1
Oquaga Creek near North Sanford:												
Linear	−1.2 × 10^{-6}	.012	(62)	4.7	2.9 × 10^{-6}	.18	(56)	1.1	1.9 × 10^{-6}	.076	(64)	.7
Hyperbolic	1.74	.0074		25.2	−1.97	.19		1.3	−.62	.074		.2
General hyperbolic	.0070	.0063	10[illegible]	5.5	.024	.18	10[illegible]	4.6	.0190	.073	10[illegible]	1.6
Gridley Creek above East Virgil:												
Linear	−.3 × 10^{-6}	.038	(54)	.5	−7.3 × 10^{-6}	.30	(55)	18.4	−25.7 × 10^{-6}	.326	(55)	27.8
Hyperbolic	−1.33	.040		4.0	11.40	.26		27.3	39.33	.197		39.4
General hyperbolic	−.019	.040	10[illegible]	3.3	.11	.23	10[illegible]	32.5	.39	.073	10[illegible]	50.7
Fivemile Creek near Kanona:												
Linear	.2 × 10^{-6}	.052	(47)	.0	−24.5 × 10^{-6}	.66	(105)	16.6	−24.0 × 10^{-6}	.36	(109)	29.0
Hyperbolic	−1.18	.061		24.0	.42	.63		.1	3.95	.30		18.5
General hyperbolic	−.080	.067	10[illegible]	29.6	.83	−.15	10[illegible]	20.2	.42	.027	10[illegible]	70.8
Conewango Creek at Waterboro:												
Linear	−1.8 × 10^{-6}	.090	(52)	4.9	−29.9 × 10^{-6}	.51	(111)	31.7	−14.2 × 10^{-6}	.20	(117)	23.6
Hyperbolic	−2.38	.052		8.7	33.79	.40		34.8	14.66	.15		22.5
General hyperbolic	−.034	.052	10[illegible]	6.6	.29	.32	10[illegible]	41.7	.13	.11	10[illegible]	27.0
Buffalo Creek at Gardenville:												
Linear	5.7 × 10^{-6}	.034	(47)	18.1	−33.2 × 10^{-6}	1.00	(104)	8.8	−3.2 × 10^{-6}	.55	(105)	.1
Hyperbolic	−8.58	.070		62.7	7.93	.094		2.1	−6.66	.57		1.9
General hyperbolic	−.17	.078	10[illegible]	67.8	.69	.34	10[illegible]	10.8	−.18	.58	10[illegible]	2.3
Black Creek at Churchville:												
Linear	3.3 × 10^{-6}	.073	(46)	1.7	−1,163.2 × 10^{-6}	6.93	(107)	42.7	−127.9 × 10^{-6}	1.44	(112)	47.3
Hyperbolic	−6.36	.099		23.8	101.3	5.12		25.6	4.87	1.28		5.4
General hyperbolic	−.14	.107	10[illegible]	26.7	9.04	1.94	10[illegible]	75.6	1.12	.40	10[illegible]	51.2
Deer River at Brasher Iron Works:												
Linear	.6 × 10^{-6}	.019	(46)	1.5	5.7 × 10^{-6}	.29	(105)	1.9	−3.5 × 10^{-6}	.069	(112)	5.0
Hyperbolic	.09	.020		.0	−1.00	.28		.1	2.14	.060		2.2
General hyperbolic	−.014	.030	10[illegible]	3.4	.25	.006	10[illegible]	2.1	.047	.039	10[illegible]	8.1

Table 8.—Results of linear, hyperbolic, and general hyperbolic relationships between chemical concentration and discharge of surface water at all stations—Continued

f(Q)	Alkalinity				Specific conductance				Total ions			
	a	b	β	100R²	a	b	β	100R²	a	b	β	100R²
East Branch Sacandaga River at Griffin:												
Linear	-0.4×10^{-3}	9.0	(115)	[3]20.3	-0.0010	49.2	(115)	[3]28.2	-0.20×10^{-4}	0.91	(65)	[3]34.9
Hyperbolic	875.5	6.4		[3]54.3	1,554.4	43.8		[3]28.3	33.73	.78		[3]38.1
General hyperbolic	13.8	4.0	$10^{-0.9}$	[3]77.7	26.0	33.4	$10^{-0.9}$	[3]60.8	.609	.54	$10^{-0.9}$	[3]83.3
Esopus Creek at Shandaken:												
Linear	$-.8\times10^{-4}$	12.9	(150)	[3]25.2	$-.0023$	58.3	(152)	[3]31.0	$-.47\times10^{-4}$	1.05	(132)	[3]34.0
Hyperbolic	860.4	9.6		[3]31.1	2,563.0	49.0		[3]43.9	50.39	.86		[3]43.9
General hyperbolic	10.4	6.4	$10^{-1.0}$	[3]44.5	34.8	44.4	$10^{-1.0}$	[3]59.1	.632	.66	$10^{-1.0}$	[3]65.2
Oquaga Creek near North Sanford:												
Linear	-4.8×10^{-3}	23.3	(66)	[3]42.3	$-.0095$	79.0	(67)	[3]41.9	-1.99×10^{-4}	1.49	(32)	[3]42.2
Hyperbolic	3,436.0	8.0		[3]68.7	6,951.7	48.6		[3]63.2	126.18	.90		[3]60.6
General hyperbolic	31.7	5.1	$10^{-1.5}$	[3]76.8	62.0	43.2	$10^{-1.5}$	[3]71.7	1.21	.77	$10^{-1.5}$	[3]79.4
Gridley Creek above East Virgil:												
Linear	-7.0×10^{-3}	74.6	(55)	[3]38.9	$-.0175$	231.	(55)	[3]44.4	-3.47×10^{-4}	4.31	(54)	[3]41.2
Hyperbolic	12,740.4	35.5		[3]77.5	28,756.3	139.		[3]73.1	613.18	2.41		[3]78.8
General hyperbolic	145.2	16.8	$10^{-0.9}$	[3]94.5	289.0	43.4	$10^{-0.9}$	[3]94.5	6.956	1.53	$10^{-0.9}$	[3]94.3
Fivemile Creek near Kanona:												
Linear	-6.5×10^{-3}	84.6	(109)	[3]25.4	$-.0175$	282.	(109)	[3]33.8	-3.29×10^{-4}	3.49	(72)	[3]34.5
Hyperbolic	1,793.4	64.0		[3]43.8	3,353.3	237.		[3]29.2	73.00	4.43		[3]36.8
General hyperbolic	111.4	17.4	$10^{-1.0}$	[3]91.5	301.7	43.0	$10^{-1.0}$	[3]81.7	5.96	1.18	$10^{-1.0}$	[3]91.9
Conewango Creek at Waterboro:												
Linear	-12.0×10^{-3}	101.6	(120)	[3]65.0	$-.0273$	280.	(120)	[3]62.7	-5.40×10^{-4}	5.34	(86)	[3]67.5
Hyperbolic	13,111.0	57.2		[3]89.8	29,075.1	180.		[3]64.0	636.18	3.42		[3]67.8
General hyperbolic	117.8	22.0	$10^{-1.0}$	[3]91.2	260.	103.	$10^{-1.0}$	[3]82.5	3.71	1.74	$10^{-1.0}$	[3]91.3
Buffalo Creek at Gardenville:												
Linear	-6.8×10^{-3}	121.5	(105)	[3]36.2	$-.0149$	396.	(105)	[3]20.6	-4.96×10^{-4}	8.11	(72)	[3]32.7
Hyperbolic	1,429.2	107.8		[2]6.6	2,024.5	370.		1.6	35.69	7.31		2.6
General hyperbolic	140.7	-14.6	$10^{-0.9}$	[3]43.7	303.2	102.	$10^{-0.9}$	[3]23.9	52.4	-44.26	$10^{-0.9}$	[3]32.8
Black Creek at Churchville:												
Linear	-5.9×10^{-3}	302.3	(116)	[2]4.7	$-.1326$	1160.	(116)	[3]58.9	-26.43×10^{-6}	24.93	(69)	[3]65.3
Hyperbolic	1,173.4	202.7		[3]15.0	6,952.4	982.		[3]13.2	136.60	20.96		[3]15.3
General hyperbolic	-79.5	215.4	$10^{-1.0}$	[3]17.3	1,222.	33.9	$10^{-1.0}$	[3]71.3	26.08	1.14	$10^{-1.0}$	[3]80.1
Deer River at Brasher Iron Works:												
Linear	-1.8×10^{-3}	51.5	(115)	[3]11.7	$-.0048$	139.	(115)	[3]15.1	$-.93\times10^{-4}$	2.89	(65)	[3]17.4
Hyperbolic	878.6	47.5		[2]3.5	2,356.8	128.		[2]4.2	110.55	2.56		[1]5.5
General hyperbolic	25.7	28.8	$10^{-1.5}$	[3]16.4	66.7	81.7	$10^{-1.0}$	[3]18.8	2.208	.80	$10^{-1.0}$	[3]22.8

[1] Indicates statistical significance $\alpha < 0.10$.
[2] Indicates statistical significance $\alpha < 0.05$.
[3] Indicates statistical significance $\alpha < 0.01$.

Table 9.—Results of best temporal-trend analysis of residual surface-water data by nonparametric seasonal Kendall test [*f*(*Q*) refers to relationship between constituent concentration and stream discharge (table 8), where M = mean, L = linear, H = hyperbolic, and G = general hyperbolic. Where no significant relationship exists, predicted constituent concentration is equal to its mean. Average percent slope (trends per year is calculated by dividing slope by the mean concentration in table 7. Location is given in fig. 1.]

Station	Hydrogen			Calcium			Ammonium			Nitrate		
	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)
East Branch Sacandaga River at Griffin	-----	-----	--	-----	-----	--	-0.0012	[1]-2.0	G	0.0060	[1]17.3	G
Esopus Creek at Shandaken	-----	-----	--	-----	-----	--	-----	-----	--	-----	-----	--
Oquaga Creek near North Sanford	26.4×10^{-6}	[3]8.1	M	-----	-----	--	-----	-----	--	.0009	[3]8.4	H
Gridley Creek above East Virgil	-----	-----	--	-----	-----	--	-----	-----	--	-.0018	[2]-4.9	M
Fivemile Creek near Kanona	1.0×10^{-5}	[3]3.8	G	-----	-----	--	-----	-----	--	-.0054	[1]-10.4	G
Conewango Creek at Waterboro	-----	-----	--	0.0194	[1]1.2	G	-----	-----	--	-----	-----	--
Buffalo Creek at at Gardenville	$-.8 \times 10^{-6}$	[1]-5.9	L	-----	-----	--	-----	-----	--	.0051	[1]11.8	G
Black Creek at Churchville	-----	-----	--	-.1066	[2]-1.4	G	-----	-----	--	-----	-----	--
Deer River at Brasher Iron Works	-3.5×10^{-6}	[1]-8.0	G	-----	-----	--	-----	-----	--	-----	-----	--

Station	Sulfate			Chloride			Total Ions			Specific Conductance			Alkalinity		
	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)	Slope	Average percent slope	f(Q)
East Branch Sacandaga River at Griffin	-0.0041	[1]-2.0	G	0.0011	[1]2.0	G	-0.0110	[1]-1.3	G	-----	-----	--	-0.083	[2]-1.0	G
Esopus Creek at Shandaken	-.0035	[1]-2.1	M	-----	-----	--	-----	-----	--	-----	-----	--	.090	[1].9	G
Oquaga Creek near North Sanford	-----	-----	--	-----	-----	--	-----	-----	--	-.5	[1]-.8	G	-----	-----	--
Gridley Creek above East Virgil	-----	-----	--	.0171	[3]7.3	G	-----	-----	--	-----	-----	--	2.072	[3]3.4	G
Fivemile Creek near Kanona	-.0100	[2]-1.6	G	-----	-----	--	-----	-----	--	3.2	[3]1.2	G	1.285	[3]1.6	G
Conewango Creek at Waterboro	-.0048	[2]-1.0	G	.0118	[3]6.8	G	.0475	[3]1.1	G	4.6	[2]2.0	G	-----	-----	--
Buffalo Creek at at Gardenville	-.0172	[3]-1.8	G	.0141	[2]2.6	M	-----	-----	--	-----	-----	--	-----	-----	--
Black Creek at Churchville	-.0776	[2]-1.4	G	-----	-----	--	-.2794	[2]-1.3	G	-----	-----	--	-----	-----	--
Deer River at Brasher Iron Works	-.0104	[1]-3.7	M	.0034	[3]5.2	G	-----	-----	--	-----	-----	--	-----	-----	--

[1] Indicates statistical significance $\alpha < 0.10$.

[2] Indicates statistical significance $\alpha < 0.05$.

[3] Indicates statistical significance $\alpha < 0.01$.

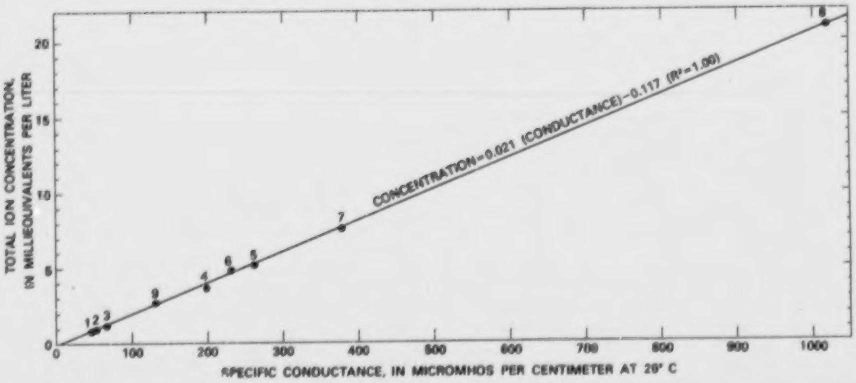

Figure 10.—Relationship between mean total ion concentration and specific conductance at all surface-water stations (numbers next to data points correspond to stations in fig.1).

SUMMARY

Chemical composition of precipitation in New York is affected by local as well as regional influences. Although the entire State has reportedly been subject to "acid precipitation" for 30 to 50 years, the concentration of free hydrogen ion has changed little on a Statewide basis for the 13-year period beginning in 1965. In the western part of the State, however, hydrogen-ion concentration seems to have increased by about 3 percent annually since 1965, equivalent to a total decrease of 0.2 pH units. In the eastern part of the State, hydrogen-ion concentration has decreased by a comparable amount. The hydrogen-ion load within the western and central parts of the State has increased slightly in recent years because precipitation quantity there has increased by an average of 2 to 3 percent annually since 1965.

Trends of sulfate, an acid-forming anion, are more easily discerned than those of hydrogen. Sulfate concentration has decreased an average of 1 to 4 percent per year. Trends in nitrate concentration were not detected at most stations. Trends in pH cannot be predicted simply from trends in these acid-forming anions, however, because dryfall contributes neutralizing material to precipitation and because chemical composition of dryfall may also change with time.

Although statistically significant trends in pH of surface water are indicated in some other areas of the State, the impact from precipitation is masked by the greater effects of agriculture and urbanization. However, Statewide decreases in sulfate concentrations in streams were detected and averaged 1 to 4 percent per year. These decreases were similar to those detected in precipitation.

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Conversion Factors and Abbreviations

The following factors may be used for converting the International System (SI) units of measure used in this report to inch-pound units:

Multiply SI units	*By*	*To obtain inch-pound units*
Length		
centimeter (cm)	2.54	inch (in.)
meter (m)	.3048	foot (ft)
kilometer (km)	.6214	mile (mi)
Area		
square kilometer (km^2)	.3861	square mile (mi^2)
Flow		
cubic meters per second (m^3/s)	35.31	cubic feet per second (ft^3/s)
cubic meters per day per square kilometer (($m^3/d)/km^2$)	91.49	cubic feet per day per square mile [($ft^3/d)/mi^2$]

Other abbreviations used in this report:
meq/L, milliequivalents per liter;
μeq, microequivalents;
(meq/L)/yr, milliequivalents per liter per year;
(μeq/L)/yr, microequivalents per liter per year;
μmho/cm at 25° C, micromhos per centimeter at 25° Celsius;
cm/yr, centimeters per year;
$km^2 \cdot d/m^3$, square kilometer-day per cubic meter;
(μmho/cm)/eq, micromhos per centimeter per equivalent.

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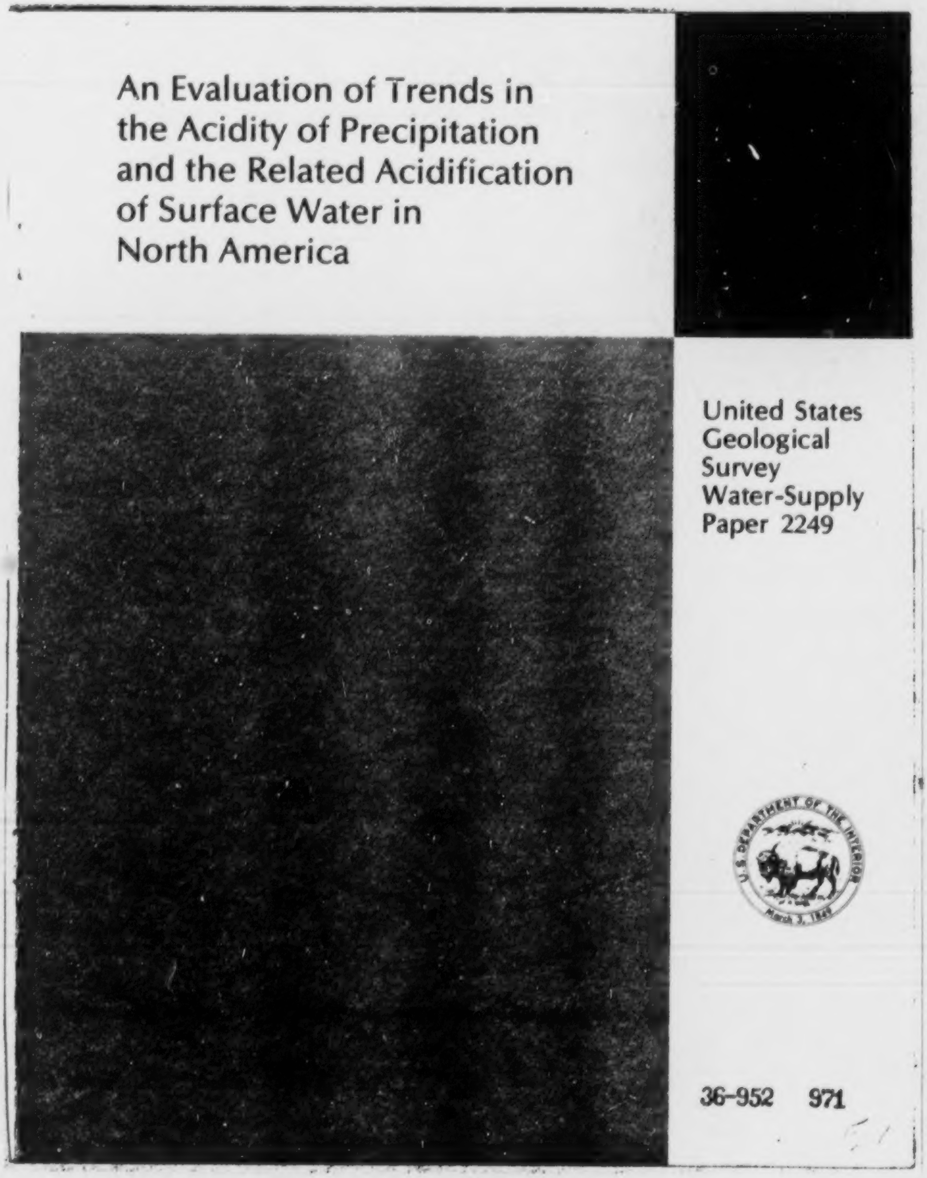

An Evaluation of Trends in the Acidity of Precipitation and the Related Acidification of Surface Water in North America

United States
Geological
Survey
Water-Supply
Paper 2249

U.S. DEPARTMENT OF THE INTERIOR
March 3, 1849

36-952 971

An Evaluation of Trends in the Acidity of Precipitation and the Related Acidification of Surface Water in North America

By JOHN T. TURK

U.S. GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2249

UNITED STATES DEPARTMENT OF THE INTERIOR
JAMES G. WATT, Secretary

GEOLOGICAL SURVEY
Dallas L. Peck, Director

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1983

For sale by the Superintendent of Documents
U. S. Government Printing Office
Washington, DC 20402

LIBRARY OF CONGRESS CATALOG NUMBER
83-600496

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An Evaluation of Trends in the Acidity of Precipitation and the Related Acidification of Surface Water in North America

By John T. Turk

Abstract

The acidity of precipitation in the Northeastern United States and Southeastern Canada has increased in the past, probably as a result of anthropogenic emissions. The increase in New England and New York occurred primarily before the mid-1950's. Since the mid-1960's, there has been no significant change in the acidity of precipitation in this region; however, sulfate concentrations have decreased and nitrate concentrations may have increased. The time of initial acidification in Southeastern Canada is not known because of a lack of historical data. In the Southeastern United States, the evaluation of whether precipitation has been acidified is complicated by meager data. The available data show that precipitation is more acidic than would be expected for sites unaffected by anthropogenic emissions. In addition, comparison of recent data with the meager historical data suggests, but does not unambiguously prove, increased acidification since the 1950's. In the Western United States, available data indicate that precipitation at individual sites has been acidified by anthropogenic emissions. The acidification generally has been attributable to localized sources, and the time of initial acidification is undefined.

Acidification of lakes and streams in the Northeastern United States has occurred in a time frame compatible with the hypothesis that acidification of precipitation was the cause. The acidification of surface waters appears to have occurred before the mid- to late 1960's. In Southeastern Canada, the best-documented cases of acidified lakes point to localized sources of acidic emissions as the cause. Sparse evidence of recent regional acidification of lakes and streams exists, but evidence for acidification of precipitation as the cause is largely lacking. In the Southeastern United States, most data on acidification of surface waters are ambiguous, and in the West, most of the data reflect local conditions. However, recent analysis of a national network of remote stream sampling stations indicates that, since the mid- to late 1960's, sulfate concentrations have increased in the Southeast and the West, with a concurrent decrease in alkalinity. Additional work is needed to test the hypothesis that regional acidification of surface waters is occurring in the Southeastern and Western United States.

INTRODUCTION

Anthropogenic, or "man-caused," acid rain is a concept that has been used to explain changes in the chemistry and biology of dilute aquatic systems in North America and northern Europe. The concept has developed over more than 100 years, first in Europe and later in North America. The historical and geographic evolution of this concept is documented in the technical literature on atmospheric chemistry, aquatic chemistry, fisheries, soils, forestry, and agriculture. An excellent summary of this evolution is given by Cowling (1982).

The regional and international nature of the acid-rain concept requires an understanding of the acidification process both in precipitation and in susceptible aquatic systems. Without an adequate understanding of the relation of the acidification process to time trends and controlling mechanisms, corrective measures cannot be developed to provide effective long-term or short-term solutions. Trend analysis can be used as a first step in the determination of important sources, transformations, and impacts of acid rain.

Trend analysis is a useful tool in many aspects of the scientific, political, and economic consideration of acid rain and its effects. Among the issues that can be addressed by trend analysis are:

1. The development of cost-effective control or mitigative procedures will require an evaluation of the importance of natural and anthropogenic sources of acidity. Similar trends in supposed sources and in impacts on precipitation or aquatic systems can serve as an aid in deciding which sources are most directly related to the impacts. Such initial decisions can provide direction to more detailed study to prove or disprove proposed relations between changes in emissions and impacts.
2. A documentation of the extent and value of damages caused by acid rain is necessary for both mitigation and assignment of legal responsibility. Trend analysis can be used to determine which geographic areas have been damaged and to assess the damage in ecologic or economic terms.

3. Definition of the watershed characteristics and processes that are most affected by acid rain, particularly with respect to the order in which changes occur, is necessary to provide the scientific understanding of how acid rain causes the changes ascribed to it. Trend analysis should be most useful in this aspect of problem definition.

The numerous uses of trend analysis with respect to acid rain have resulted in exhaustive searches for data bases which might allow trend detection. Unfortunately, the collection of data in past studies has resulted in data bases that normally do not meet all the needs of a trend analysis. Because investigators in previous studies did not know the uses to which their data would be applied, crucial measurements often were not made. Similarly, documentation of methodology and quality control are lacking. In comparing older data with recent data, changes in analytical methodology further complicate trend detection. As a result, the capability of trend analyses to show trends has varied among geographic areas, individual chemical constituents, and data bases. Further, reports generally have been quite limited in the geographic area covered by the investigator. Most studies have been local or statewide, and only a few have been regional in scope. Only one study, limited to surface waters, has been conducted on a nationwide scale (Smith and Alexander, 1983).

Purpose and Scope

This report is intended to critically evaluate published trend information about the chemical quality of precipitation and of dilute surface waters that may have been significantly affected by changes in precipitation quality. The results of several studies within individual geographic regions were combined to assess whether changes in chemical quality have occurred. To the extent that the available data permit, several hypotheses on why trends are or are not found are evaluated. It is beyond the scope of this study, however, to provide new data or new trend analyses of data used in previous publications.

In addition to evaluating whether trends in acidification have occurred, this report assesses the certainty of assigning time periods for the initiation of reported changes. While it may seem trivial whether an area became acidified in the last 10, 50, or 100 years, this is not the case. Our understanding of the response of precipitation to changes in atmospheric emissions, at least in terms of long-term average responses, is seriously hampered by the uncertainty in estimating rates of change in acidification in specific regions. If historical data are inadequate to address this question, then estimates of response must be made on assumptions untested for long-term validity, or must be postponed until an adequate data base can be developed. In the application of expensive mitigative or preventive measures to serious environmental problems, neither alternative is desirable.

Acknowledgments

This study was greatly assisted by the cooperation of researchers who provided information on applicable publications and made available copies of their work, often before they were printed. Denise Wiltshire, of the U.S. Geological Survey in Albany, N. Y., provided an invaluable contribution with a streamlined bibliographic search, preliminary review of content, and retrieval. Owen Bricker, Robert Hirsch, Douglas Manigold, and David Rickert of the Geological Survey provided numerous improvements to the manuscript.

APPROACH

Literature Search

Reviewing the literature on trends in the acidity of precipitation and surface water entailed: (1) conducting computerized bibliographic searches of the data bases listed in table 1; (2) searching published bibliographies of

Table 1. Description of data bases searched

Name of data base	Time coverage of data base	Description
Aqualine	1974 to present	Indexing data base of the Water Research Center, Buckinghamshire, England
CA Search	1967 to present	Online version of Chemical Abstracts
Enviroline	1970 to present	Bibliographic data base for environmental energy information produced by Environment Information Center, N.Y.
GEOREF	1961 to present	Earth-sciences data base produced by American Geological Institute, Falls Church, Va.
NTIS	1964 to present	Data base of government-sponsored research reports produced by National Technical Information Service, Springfield, Va.
Pollution Abstracts	1970 to present	Online version of Pollution Abstracts
Selected Water-Resources Abstracts	1968 to present	Online version of Selected Water-Resources Abstracts

Rambo and Karanas (1982), Dailey and Winslow (1980), and Wiltshire and Evans (1983); and (3) communicating with scientists researching acid precipitation.

Keywords used in searching the computerized bibliographies are listed in table 2. Keywords were selected from the "Water Resources Thesaurus" (U.S. Office of Water Research and Technology, 1980), "GEOREF Thesaurus and Guide to Indexing" (Riley, 1981), and "Enviroline User's Manual, appendix F", Keyword Lists (Environment Information Center, 1982).

Results of the computerized and manual literature searches were reviewed. Retrieved documents were assessed for relevance to the scope of investigation and evaluated for problems that could influence the reliability of the conclusions.

Evaluation of Trend Data

Although the purpose of this work is to develop a continental-scale evaluation of trends in the acidification of precipitation and changes in surface-water chemistry that can be attributed to acid rain, it is useful to consider separately the published information by geographic area and by type of data (precipitation or surface water). The usefulness of this approach is that changes in anthropogenic emissions to the atmosphere have not occurred uniformly in time, in chemical composition, or in magnitude for all sections of North America. Further, the prevailing westerly movement of weather systems across the United States tends to cause certain clusters of emissions sources to affect the precipitation quality in regions that are somewhat stratified by latitude (fig. 1). For example, emissions in the Northeastern United States often influence the quality of precipitation in that part of the Nation, and only infrequently affect the quality in the Southeastern United States. Because the scatter in chemical-concentration data is often related to the concentration, very dilute water such as precipitation may exhibit a significant trend but more concentrated surface-water data may not, even though both have trends of the same magnitude. Thus, it is useful to consider the trend information for precipitation separately from that for surface water. Unavailability of trend data from Mexico and much of Canada makes analysis on a continental scale difficult.

Table 2. Keywords used in bibliographic searches

Terms related to precipitation chemistry	Terms related to trend analysis
Acid rain	Trend(s)
Acid precipitation	Temporal distribution
Acidic deposition	Spatial distribution
Acidic water	History
Sulfate, sulfates	
Nitrate, nitrates	
Hydrogen-ion concentration	

In addition to the usefulness of considering geographic area, precipitation, and surface water as class variables and thereby restricting the investigation to these classes, some consideration also must be given to what actually constitutes a significant trend. In the simplest sense, a time trend can be defined as a statistically significant difference in some variable—alkalinity, sulfate, nitrate, or pH—between two time periods. In such a case, a set of measurements of the variable of interest, with sufficient information on random and systematic errors affecting measurements in both time periods, is the only information necessary to determine whether a trend has occurred. Unfortunately, these ancillary data are commonly not available. In these instances, some estimate of the range of measurement error and bias must be applied to judge the liklihood of a trend actually existing.

Many of the sources of error inherent in the simple comparison of the mean value of a variable in two separate time periods can be estimated or minimized if a continuous data set is available rather than a separate, short-term set for two separate time periods. Errors caused by seasonality, changes in analytical methodology, climatic variability, and other sources can be addressed more adequately in a continuous data set. Unfortunately, such data bases tend to be much less commonly reported than mean values.

Given that the most appropriate data sets are not routinely available for the class variables considered, some mix of mean value and continuous data is necessary to perform an analysis for trends. The approach used in this report is to consider the sources of error that can be approximated and to examine the consistencies or inconsistencies of the trends among the data sets available. As a contribution to future work of this type, some suggestions for improvements in data collection are given.

RESULTS

pH of Natural Precipitation

The pH of natural precipitation is of great importance in detecting trends in acidity where reliable historical data are not available. Early work assumed a natural pH of about 5.6 (Likens, 1976), the pH of pure water in equilibrium with atmospheric carbon dioxide. While acidification relative to some presumed fixed level of acidity would seem an easy calculation, data indicate that a range of pH from about 4.5 to 5.6, rather than a fixed

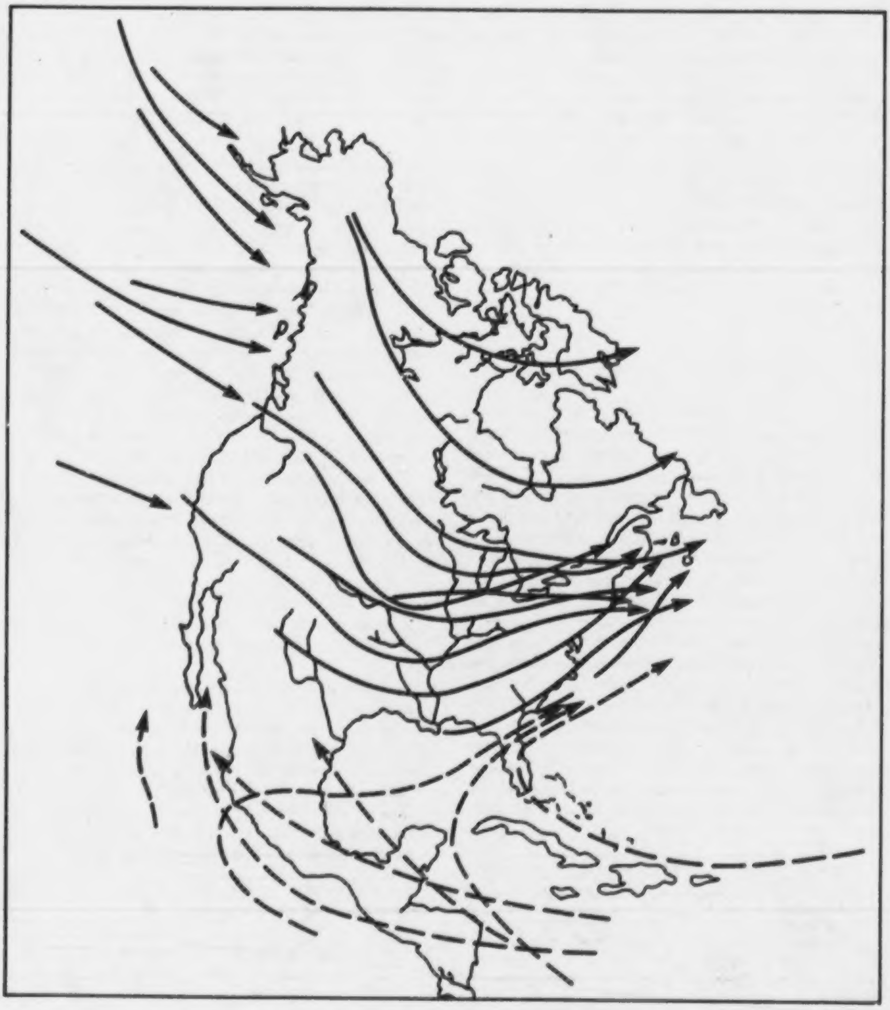

Figure 1. Major climatological storm tracks for the North American continent. (Adapted from Haurwitz and Austin, 1944).

value of 5.6, should be expected in precipitation in the absence of significant anthropogenic acidification. This range of pH values is derived from consideration of the natural sulfur, nitrogen, and water cycles (Charlson and Rodhe, 1982). Indeed, the average pH of precipitation in locations remote from local anthropogenic acidification sources has been shown to be 4.8 to 5.0 (Galloway and others, 1982), although some part of this acidity is probably due to long-range transport from more developed areas. Galloway and others (1982) state the "...lower limit of the natural mean pH was probably ≥5." A significant part of the natural acidity probably was contributed by formic and acetic acids which were shown to be important in some of the samples. Thus, acidification should not be presumed as an excess of hydrogen ion relative to arbitrary, calculated pH values based on oversimplifying assumptions such as equilibration with atmospheric carbon dioxide as the only natural acidification control. The natural pH is probably a very site-specific value, with its magnitude at a site subject to natural temporal variation. Values of pH will be a function of at least global and local climate, additions of weak and strong acids, and additions of alkaline ions and compounds—the additions being contributed now by both natural and anthropogenic processes.

Midwestern-Northeastern United States and Southeastern Canada

Synoptic Data Indicating Trends in Precipitation Acidification

The data base for this geographic area (fig. 2) is the best documented, the most cited, and the most influential in addressing the acid-rain topic. Both mean-value and continuous-sampling data sets are available. Of the regional-scale data bases for which a reasonable degree of quality-control information is available, that collected in the period 1955–56 (Junge and Gustafson, 1956; Junge, 1958; and Junge and Werby, 1958) is the oldest. Later multisite synoptic data sets include those reported by Lodge and others (1968), Gambell and Fisher (1966), and Pearson and Fisher (1971). These data, combined with subsequent data from numerous sources, form the principal basis for the hypothesis that precipitation has undergone acidification both in intensity and areal extent during the past few decades (Cogbill, 1976; Cogbill and Likens, 1974; Likens, 1976; Likens and others, 1979; and Likens and Butler, 1981). Acidification has been inferred because of differences in pH relative to a presumed value of the natural pH of about 5.6, and because of differences in pH among the synoptic data sets as a function of time and location (figs. 2 and 3). Although the assumption of a natural precipitation pH of 5.6 is unsupportable, pH isopleths less than about 5.0 (Cogbill and Likens, 1974) probably delineate areas of anthropogenically acidified precipitation. In 1955–56, this included the area bounded by Ohio on the west, North Carolina on the south, and Maine on the northeast.

The importance of the regional synoptic data sets from 1955 to 1966 in the hypothesis of regional acidification of precipitation has resulted in several thorough reviews of potential errors and biases that may complicate the comparison of these early data with more recent data. Perhaps the most serious potential problem is the necessity of using calculated pH values for data lacking direct measurement. An error analysis by Liljestrand and Morgan (1979) indicated that, assuming a coefficient of variation of 10 percent in the major-ion data used to compute pH in early data sets, the 68.3-percent confidence limits at an actual pH of 5.65 are 5.17 and 6.13. The errors in calculation of pH are much smaller for more acidic pH values. Thus, errors should be greatest for southeastern and midwestern sites with pH values greater than 5.0, and least for the very acidic northeastern sites. Assuming the coefficient of variation is not larger than 10 percent, the authors conclude that the hypothesis of increasing acidity is valid for the northeastern United States from 1955 to 1966.

The errors associated with the analyses of individual elements in the synoptic data sets generally fall within a maximum range of 10 percent (Hansen and others, 1981). Analysis of additional sources of error (Hansen and others, 1981; Hansen and Hidy, 1982) indicate possible systematic error in pH of up to 0.2 and random error of 0.7 in the 1955–56 data for pH, while the 1965–66 data are calculated to have a systematic bias of -0.6 and a random error of 0.5. These studies conclude that the data sets are of "... insufficient quality and quantity to support any long-term trends in precipitation-acidity change in the eastern United States. However, the observations do show that precipitation is definitely acidic over this region, and is probably more acidic than expected from natural baseline conditions."

Although precipitation in parts of the Northeastern United States has been detectably acidified, the hypothesis that there has been a rapid expansion of this acidification to the south and west is less certain. The basis for the hypothesis is the difference in precipitation pH calculated from the data of Junge and Gustafson (1956) and the measured or calculated pH values from numerous later sources (Likens and Butler, 1981). The proposed acidification of

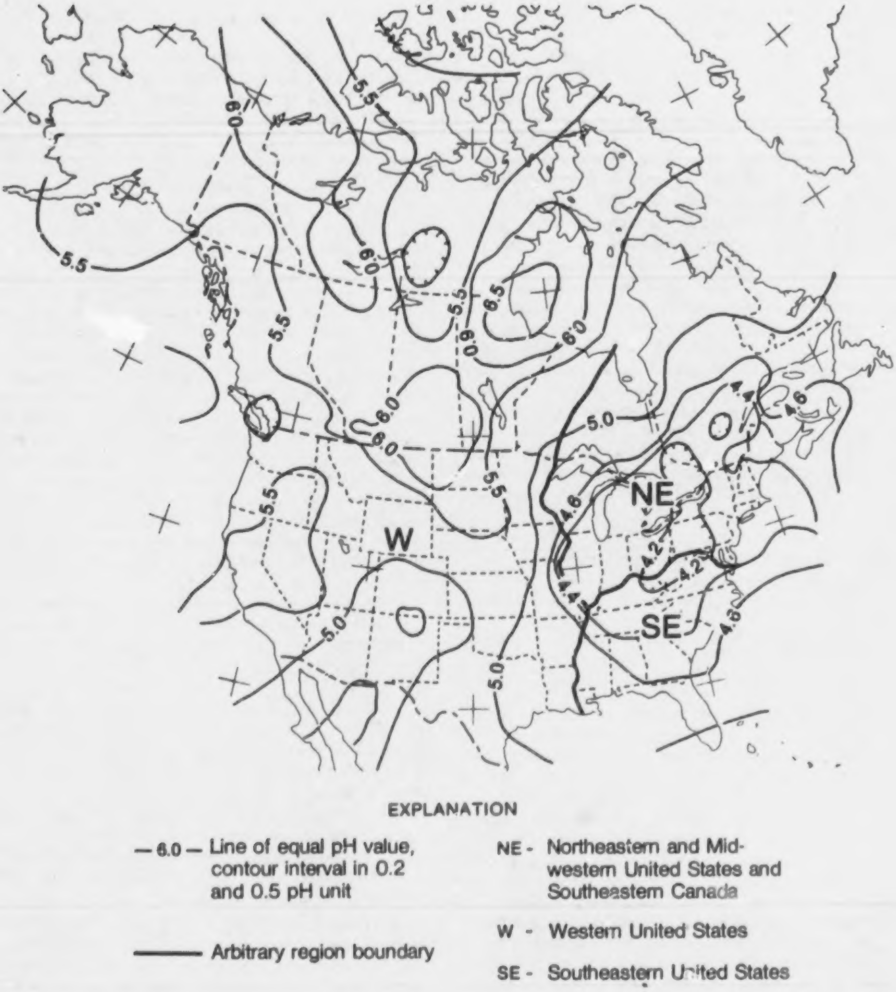
5.5
6.0
6.5
5.0
4.8
4.6
4.4
4.2
NE
W
SE
EXPLANATION
— 6.0 — Line of equal pH value, contour interval in 0.2 and 0.5 pH unit
Arbitrary region boundary
NE - Northeastern and Midwestern United States and Southeastern Canada
W - Western United States
SE - Southeastern United States

Figure 2. Precipitation weighted, average annual pH of precipitation in North America, January-December 1981; and arbitrary boundary for regions addressed in this report. Isopleth map based on data from National Atmospheric Deposition Program and Canadian Network for Sampling Precipitation, reproduced by permission of the National Atmospheric Deposition Program.

precipitation in the Southeast since the mid-1950's will be discussed in a following section of this report.

Acidification since the mid-1950's in the Midwest has been critically evaluated in several reports. There are problems in defining pH isopleths for the Midwest because of low density of data points and because data are "almost exclusively...from the urban Chicago and Cincinnati sites..." (Hansen and Hidy, 1982). The authors further analyze and attempt to quantify systematic and random errors associated with the measurement and calculation of pH, concluding (as noted previously) that the data are insufficient to support the westward expansion of acidification.

The influence of dust, enhanced by the drought of the mid-1950's was evaluated for a site in central Illinois (Stensland, 1980). Between 1954 and 1977, a minor increase in emission-related sulfate, a 50-percent increase in emission-related nitrate, and an 85-percent decrease in soil-derived calcium plus magnesium were observed. The decrease in pH from 6.05 in the mid-1950's to recent (1978) values of about 4.1 was attributable almost entirely to the calculated to be 4.2 instead of 6.05 after adjustment for the change in concentration of calcium plus magnesium caused by drought.

The influence of climatic variation on the data collected during the mid-1950's was further investigated for sites in Illinois, New York, Pennsylvania, and Virginia (Stensland and Semonin, 1982). In all cases, there was an increase of 30 to 72 percent in the concentration of nitrate and a larger (73 to 88 percent) decrease in the concentration of calcium plus magnesium between the mid-1950's and the late 1970's. Sulfate increased at the Illinois site, but decreased by 3 to 23 percent at the other sites. Thus, changes in the contribution of alkaline materials from natural sources is as probable a cause for observed changes in pH as is an increase in acidic materials

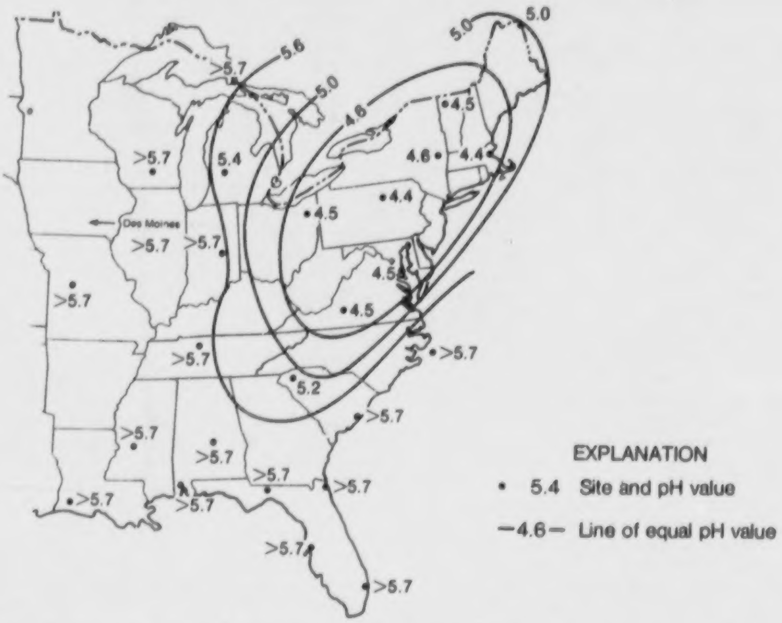

Figure 3. Isopleth map of pH based on H+ concentrations calculated by Likens and Butler (1981) for the 1955–56 precipitation data.

from emissions sources. On a chemical equivalent basis, the change in alkaline materials is greater than the change in acidic materials.

Although most historical data on precipitation chemistry for this region of North America are from the United States, some data are available from Canada. Data for the period 1952–54 are available for Kentville, Nova Scotia (Herman and Gorham, 1957), indicating an average pH of about 5.7. Collection in copper rain gages, which were used in the Canadian study, rapidly neutralizes acidic solutions and produces pH values much greater than those of the initial solution (Kramer and Tessier, 1982). Thus, the measured pH data from this study do not necessarily indicate nonacidified precipitation during the early 1950's.

More recent data from Canada (Summers and Whelpdale, 1976; Dillon and others, 1978) indicate pH values much less than those expected for unacidified precipitation, averaging from about 4.0 to about 5.0. Unfortunately, the lack of reliable historical data severely limits the ability to estimate either the time of the onset of acidification or the acidification rates.

Continuous-Collection Data Indicating Trends in Precipitation Acidification

Although continuous-collection data sets have some of the problems of synoptic data sets, time-trend analysis on continuous sets often can avoid problems such as systematic error from methodology changes, the effects of short-term climatic variations and seasonality, and other problems that complicate the interpretation of changes in synoptic data sets. Examples of these problems were demonstrated by conflicting short-term trends in pH (Likens and others, 1980), step-function changes in nitrate concentration associated with analytical changes (Peters and others, 1982), and major effects on the statistical significance of trends caused by climatological extremes at the beginning and end of a record period (Likens and others, 1980).

Most of the time-trend analyses of continuous-collection data sets have concentrated on data from the Hubbard Brook Ecosystem Study (Likens and others, 1980), which commenced in 1963, and on the data from a multisite network of stations operated by the U.S. Geological Survey in New York and Pennsylvania beginning in 1965 (Peters and others, 1982). After careful consideration is given to problems complicating the interpretation of data, both data sets continue to show significant trends in precipitation chemistry. Comparison of the two data sets indicates the value of comparing data from several sites, and of having an extensive period of record, before making generalizations on time trends in precipitation quality.

The Hubbard Brook data indicate no time-trend in pH during the 1964–77 period, although short-term trends within this period "would have given conclusions conflicting with one another and with the lack of trend for the entire period" (Likens and others, 1980). The U.S. Geological Survey data (Peters and others, 1982) indicate a slight decrease in pH of about 0.2 at the stations in western New York, with a corresponding increase at the eastern New York sites, over the period 1965–78. Using linear time-trend analysis, both data sets indicate a decrease in sulfate concentrations, with three of the New York sites showing declines and only one showing an increase. Use of the nonparametric seasonal Kendall test on the New York data yielded a decrease in sulfate concentration at six sites and an increase in sulfate concentrations at one site (Peters and others, 1982). The Hubbard Brook data indicate "nitrate concentrations in precipitation increased rather markedly after 1964...but have not increased much since about 1970–1971" (Likens and others, 1980), while the New York data "suggest that nitrate increased at eight of nine stations" (Peters and others, 1982). An analytical methodology change in 1969 may have accounted for some of the supposed increase in nitrate in the U.S. Geological Survey data.

In assessing the role of various ions as possible controls on the acidity of precipitation, regression analyses of nitrate and sulfate against hydrogen ion, on an equivalent basis, were performed for both the Hubbard Brook Study data and the U.S. Geological Survey data. For the Hubbard Brook Study data, the loading of sulfate correlates poorly with acid loading, with much of the correlation apparently a result of climate extremes in two of the years of data collection. Nitrate loading, however, correlates on an approximately equivalent basis with acid loading. The U.S. Geological Survey data indicate a better correlation between acid loading and sulfate than between acid loading and nitrate; however, only the nitrate data after the 1969 analytical method change were used for the correlation, while the entire period of record was used for the sulfate correlation.

Nitrate concentrations during the last 100 years, converted to normalized loading rates for eastern North America, indicate a substantial increase between about 1950 and 1970. The loading was approximately equal to calculated nitrogen oxide emissions from combustion processes (Brimblecombe and Stedman, 1982).

Trends in Surface-Water Acidification

This topic has been very thoroughly discussed in two recent summary reports (United States-Canada Impact Assesment Working Group 1, 1983; U.S. Environmental Protection Agency, 1983b). The reader is referred to these two documents for additional detail on the summary presented here. Reference is also made to studies not included in the two summary reports.

As with precipitation chemistry, both synoptic and continuous-collection data bases are available. Comparisons, especially between synoptic data bases, are complicated by many of the same factors affecting synoptic precipitation-chemistry data sets—for example, climatic variations, changes in analytical methodology, and seasonality. An excellent review of problems caused by changes in analytical methodology and suggestions on how to quantitatively correct for many of the problems is presented by Kramer and Tessier (1982).

As shown in the summary reports (United States-Canada Impact Assessment Working Group 1, 1983; U.S. Environmental Protection Agency, 1983b), trends in surface-water chemistry of this region commonly indicate decreases in alkalinity and pH. Many of the Canadian studies cited in the two reports document aquatic-chemistry changes that may be caused by local sources of emissions—for example, the Sudbury smelting operations and emissions from municipalities near the lakes studied (Beamish and Harvey, 1972; Beamish and others, 1975; and Watt and others, 1979). Other studies found similar changes in chemistry for systems thought to receive precipitation loading derived from more regionally representative air masses—for example, Clear Lake and Walker Lake in south-central Ontario are shown to have decreased in alkalinity from about 1970 to 1976 (Dillon and others, 1978). If the data are examined for changes in acidic anions, however, only the data for Clear Lake indicate sufficiently large changes in the concentration of sulfate to account for the supposed change in alkalinity. Other lakes in the vicinity showed alkalinity values less than 200 μeq/L (microequivalents per liter); however, data were not available to indicate historical values (Dillon and others, 1978). Time trends in the chemistry of 11 rivers in Atlantic Canada, primarily in Nova Scotia and Newfoundland, indicate no trends or decreasing trends in pH for the eight rivers having the least alkalinity. Sulfate trends were roughly balanced among decreasing, increasing, and stationary concentrations (Clair and Whitfield, 1983).

Data on trends in surface-water chemistry that may be related to precipitation chemistry indicate decreases in pH and alkalinity of lakes in New England and New York over the period from the 1930's to the 1970's (Davis and others, 1978; Norton and others, 1981; Burns and others, 1981; Schofield, 1976; and Pfeiffer and Festa, 1980). These have been recently reviewed and summarized (United States-Canada Impact Assessment Working Group 1, 1983; U.S. Environmental Protection Agency, 1983b). Although climatic and seasonal effects on pH and alkalinity generally are not addressed adequately in these reviews, the effects of changes in measurement techniques on reported pH are considered. Use of both modern and historical pH-measurement techniques (Norton and others, 1981; Burns and others, 1981; and Pfeiffer and Festa, 1980), as well as consideration of systematic errors in colorimetric pH measurements (Kramer and Tessier, 1982), indicate the reported decreases in pH since the 1930's probably are correct. Unfortunately, few historical alkalinity data are available in these studies; however, the data that exist indicate decreases of approximately 100 μeq/L.

Acid precipitation is credited with the alkalization of Weber Lake in Michigan. Nitrate uptake by plants and sulfate reduction by bacteria are reported to have increased the rate of carbonate weathering at Weber Lake, where "...Weathering rates have increased as an indirect result of acid precipitation" (Kilham, 1982).

Data also are available for streams in the Northeastern United States. Data for nine streams having a wide variety of land use and geographically distributed across New York State were examined for trends in chemistry (Peters and others, 1982). After correcting for the effects of stream discharge on chemical concentration, statistically significant decreases in sulfate concentration were found for seven of the streams from the mid-1960's to the mid-1970's. Alkalinity values increased in three streams and decreased in one stream. Nitrate values showed no consistent trend. The mean alkalinity at the sites was relatively large, ranging from 170 to over 3,900 μeq/L. Thus, the lack of any consistent trend in hydrogen-ion activity and, to a lesser extent, alkalinity, is not unexpected. Hydrogen-ion activity would be an insensitive measure of acidification in these moderately- to well-buffered streams. Natural variations in alkalinity seemingly are great enough to overshadow the slight fluctuations in precipitation acidity shown for this region (see preceding sections on trends in precipitation acidification for the Northeastern United States).

Data for pH are available from a U.S. Geological Survey Hydrologic Bench-Mark station and a second headwater stream in New Jersey (Johnson, 1979; Smith and Alexander, 1983). The pH values are low enough that the presence of bicarbonate buffering should be negligible. Thus, hydrogen-ion activity would respond in direct proportion to additions of acid and be a sensitive indicator of acidification. Johnson (1979) regressed pH against time for the two stations for the period 1963–1978. The results showed increases in hydrogen-ion concentrations at both stations, which ranged from 26 to 80 μeq/L depending upon how the data were censored. Smith and Alexander (1983) subsequently analyzed the Hydrologic Bench-Mark data for the period 1973–1981 (excluding pH values prior to 1973 which were measured in the laboratory instead of the field) and found no trend in pH. The same authors also analyzed other data collected at the site beginning in 1966 and found an increase in alkalinity and a decrease in sulfate.

Two reports are available on the chemistry of streams in Pennsylvania (Arnold and others, 1980; Ritter and Brown, 1981). The former report has been extensively criticized (U.S. Environmental Protection Agency, 1983b); deficiencies reported were primarily a failure to discuss sites at which pH and alkalinity showed no trends or increasing trends, and the inclusion of very short-term changes (for example, 1 year) in the comparisons. Three hundred and fourteen stations were found which had data for at least two samples collected at least 1 year apart. Of this total, 207 stations showed a decrease in neither pH nor alkalinity, whereas the remaining 107 stations showed a decrease in either pH, alkalinity, or both. Although the data at two-thirds of the stations are consistent with no increase or a decrease in acid deposition, the deficiencies of the study render the results inconclusive.

The second report on trends in the chemistry of Pennsylvania streams (Ritter and Brown, 1981) compared samples collected during low-flow conditions in 1979–80 with samples collected prior to 1971. After selection of historical samples representing similar flow and specific conductance, most sample comparisons indicate a decrease in sulfate and alkalinity and possibly an increase in pH. Rigorous testing of the changes was not performed, although the graphical methods seem convincing for sulfate and alkalinity. However, the selection of the time period of low-flow, although simplifying the comparison of data, may have biased the data to the period of least sensitivity to acidification effects. The enhanced opportunity for soil-water interactions to prevail during these conditions would be expected to influence the pH and alkalinity. The results of this study are also inconclusive.

A wide array of stream chemistry data are available in the Northeast from eight stations of the national Hydrologic Bench-Mark Network (Smith and Alexander, 1983). Depending on the station, the alkalinity and pH records are continuous since the mid- to late 1960's, whereas records of field-measured pH are continuous since the late 1960's or early 1970's. Trend analysis testing showed a general regional pattern of increases in alkalinity, decreases in sulfate, and mixed results for pH. Collectively, the results suggest a decrease in acid deposition in the Northeast since the mid- to late 1960's.

Southeastern United States

Trends in Precipitation Acidification

Changes in the acidity of precipitation for this region are inferred from differences in synoptic data bases (figs. 2 and 3). The general geographic expansion of acidification cited in the previous section for the Midwestern United States has also been hypothesized for the Southeastern United States (Likens and Butler, 1981). The historical synoptic data set is that of Junge and Gustafson (1956), while a composite of measured and calculated pH values obtained later was used to indicate change. Error analysis indicates that this approach is inconclusive for the Southeastern United States "...because of the uncertainty in the calculated values around pH 5.6," where both random and systematic errors in the calculation of precipitation pH are largest (Liljestrand and Morgan, 1979). Thus, comparison of historical and recent data must be supplemented with indirect data, such as the pH range of natural precipitation, to deduce trends in acidification.

Additional comparisons to the synoptic data of the mid-1950's have been made for Gainesville, Fla. (Hendry and Brezonik, 1980) and other sites throughout Florida (Brezonik and others, 1980). Average values of pH ranged from about 4.5 in northern Florida to about 5.5 in southern Florida. Sulfate concentration increases since the mid-1950's are hypothesized to account for most of the present acidification; however, increases in nitrate concentration are shown to be much larger as a precentage of the base period (Brezonik and others, 1980). In the analysis of data collected in Florida and other areas in the Southeastern United States, it was concluded that "On an areawide basis there is an apparent decrease of approximately 1 pH unit between the 1950's and 1970's" (Hansen and Hidy, 1982). The increase in acidity was attributed either to changes in climate, thereby affecting the proportion of low pH marine air to continental air, or to increases in population, motor vehicles, and power production.

In an analysis of spatial variation in precipitation chemistry in coastal South Carolina, the average pH was found to be about 4.3 (Richter and others, 1983). Sulfate deposition was approximately four times the nitrate contribution and, even with the coastal location, oceanic sulfate accounted for only about 9 percent of the total sulfate loading.

Trends in Surface-Water Acidification

In a comparison of pH and alkalinity data collected in North Carolina during the early 1960's with data from the same sites during 1979, no significant change in pH was detected (Burns and others, 1981). The authors attributed the lack of change in pH to the fact that significant amounts of alkalinity (average alkalinity = 80 μeq/L) were available; thus, pH would be an insensitive indicator of acidification status.

To determine if the alkalinity concentrations were different between the two data sets, Burns and others (1981) first addressed the effects of changes in analytical methodology. In the early 1960's study, a methyl-orange colorimetric technique was used to determine the alkalinity endpoint; however, in the 1979 study an electrometric endpoint determination was used. The authors subtracted 32 μeq/L of alkalinity from the historical data to correct these data for the amount of free hydrogen ion in solution at the presumed endpoint pH of 4.5. After making this correction, the authors noted a statistically significant ($p = 0.02$) decrease in alkalinity concentration of about 34 μeq/L. The correction used by the authors has since been shown to be in error (Kramer and Tessier, 1982). The appropriate correction in dilute samples is approximately 81 μeq/L, rather than 32 μeq/L, because the methyl-orange endpoint in dilute solutions is at a pH of about 4.0 rather than 4.5. If this larger correction value is subtracted from the historical data, the trend in alkalinity is an increase rather than a decrease in recent years (Kramer and Tessier, 1982). Thus, neither the pH nor alkalinity values indicate acidification between the early 1960's and 1979.

A comparison of alkalinity concentration to the sum of the four major cations, in μeq/L, also was made to estimate the degree of acidification (Burns and others, 1981). A ratio of about 1 would indicate that most chemical weathering was the result of reaction between carbon dioxide and soil minerals. Ratios much less than 1 would indicate weathering by other acids, such as those from acid rain. The observed ratio of 0.562 was interpreted to indicate that some acidification had taken place. Data pertaining to this ratio were unavailable from the historical data base. The ratios for two areas presumed to be acidified were 0.064 (Scandinavia) and 0.185 (La Cloche Mountains, Canada), while three presumably unacidified regions yielded ratios of 0.776 to 0.942. To be used as an index of acidification, no significant amount of anions other than bicarbonate can be derived from chemical weathering or from precipitation, unless balanced by an equivalent amount of hydrogen ion in precipitation. Burns and others (1981) provide no information to indicate whether these conditions were met.

In an analysis of trends in the chemistry of the Neuse River, N. C., an increase of approximately 50 percent in sulfate concentration from 1955 to 1975 was noted (Harned, 1982); this increase was attributed to atmospheric loading. No comparison of the sulfate concentration in precipitation was made to indicate the appropriateness of the magnitude; however, other work in the same area (Munger and Eisenreich, 1983) indicates sulfate concentrations in precipitation of about 1.5 to 2.0 mg/L (milligram per liter). Considering that the probable level of evapotranspirative enhancement in the area is around 2–3, a significant part of the sulfate concentration of 10 mg/L in the Neuse River most likely results from precipitation loading.

Thirteen lakes in northern Florida were shown to be significantly different in pH from seven lakes in southern Florida (Crisman and others, 1980). The authors attribute the difference to variations in acidity of precipitation in the two areas; however, no data are presented to indicate that the lake groups should be comparable. The authors also state that pH and alkalinity in the northern Florida lakes have decreased during the last 20 years, while sulfate concentrations have increased. No documentation for the conclusions was provided in the report.

On a regional basis, stream chemistry data are available in the Southeast for nine stations of the Hydrologic Bench-Mark Nework (Smith and Alexander, 1983). Collection of data began between the mid-1960's to the early 1970's, depending upon the station and the specific chemical constituent. Trend analysis testing for the nine stations has yielded a regional picture for pH which is balanced between decreases and no change; a mixed picture for alkalinity, with an equal number of increases, decreases, and no change; and a definite regional trend of increases in sulfate. Collectively, the Bench-Mark data in the Southeast are consistent with an increase in acid deposition over the period of record.

Western North America

Trends in Precipitation Acidification

Precipitation chemistry for this region is documented at a few sites, but only for the very recent time period. Although the region logically could be divided into numerous smaller areas based on differences in emission sources, the lack of data limits the usefulness of this approach. The first documentation of trends in the region is for the area 6 kilometers east of the Continental Divide in Boulder County, Colo. (Lewis and Grant, 1980). During a period of 150 weeks beginning in 1975, weekly bulk deposition samples indicated a linear decrease of about 0.8 in pH. The magnitude of the hydrogen-ion loading increase was balanced by an equivalent increase in the loading of nitrate. Sulfate did not have a significant ($P = 0.05$) trend with time, and was only slightly greater in loading rate than was nitrate—196 compared to 129 equivalents per hectare per year (Grant and Lewis, 1982).

The lack of additional stations in the area complicated the assignment of source areas. There was further complication because of the proximity to the highly urbanized Denver Front Range metropolitan area (Lewis and Grant, 1980; Kelly and Stedman, 1980). Although a detailed meteorological study of the relationship of episodic upslope wind to precipitation chemistry was not available for the period of study reported by Lewis and Grant (1980), a study of the relationship was made by Kelly and Stedman (1980). The results showed that from January to July, when upslope conditions are the most prevalent, a hundredfold increase in concentrations of pollutants in air masses from the metropolitan area is the main factor influencing average concentration during collection periods of about a week, such as was employed in the work of Lewis and Grant (1980). In reply to Kelly and Stedman (1980), Lewis and Grant (1980) agreed that the effect of metropolitan contributions are a "...potential source of the mineral acids in precipitation near the Continental Divide, but very forceful and frequent year-round upslope movements are required, against strong prevailing weather patterns in certain months, in order to account fully for the acidity...." The possible problems associated with the extrapolation of short-term trends in precipitation chemistry were illustrated by the Hubbard Brook data (Likens and others, 1980). Thus, the results of these observations should be considered indicative only of the 1975–78 period. To determine the relative importance of regional air masses to local ones, additional sites, a longer period of record, and combined meteorological/precipitation-chemistry studies will be required.

Very recently, a detailed meteorological study of atmospheric and precipitation chemistry was performed in the areas studied by Lewis and Grant (Huebert and others, 1983). These authors concluded, "Thus, although the wind is from the east only a small fraction of the time, the almost order-of-magnitude greater NO_x and HNO_3 concentrations associated with these winds imply that at least 60 percent of the total concentration of these species during the entire observing period came from sources to the east. This is a conservative percentage since it does not include concentrations observed during light and variable wind conditions, which do include some short duration and weak east-wind conditions."

Short-term data are available for the area near Gothic, Colo. (John Harte, Lawrence Berkeley Laboratory, written commun., 1983). The average pH in samples collected since 1980 and weighted for the amount of precipitation, is 4.55. The nitrate-to-sulfate equivalent ratio, which averages 0.9, is greater than the 0.7 value reported east of the Continental Divide (Grant and Lewis, 1982). Although the time period for trend determination was insufficient, the average pH is lower than expected at remote sites (Galloway and others, 1982; Charlson and Rodhe, 1982).

The volume-weighted mean pH of precipitation samples collected in Pasadena, Calif., from 1976 to 1977 was 4.06 (Liljestrand and Morgan, 1978). The average nitrate-to-sulfate equivalent ratio was 1.25, or 1.32 after subtraction of the marine sulfate component. The authors noted the period of collection was one of anomalous weather. A drought occurred during the sampling period, and two individual storms accounted for 20 percent of the total precipitation. Because the site is urban, the results are unlikely to be representative of the region.

During January through July 1981, the average pH at five sites in the Cascade Mountains east of Puget Sound, Wash., was about 4.7, with an average nitrate-to-sulfate equivalent ratio of 0.8. The ratio was about 0.7 after subtraction of the marine sulfate component (Logan and others, 1982). Although the period of data collection was brief, the data indicate slightly more acidic conditions than the lower limit estimated for unpolluted remote sites.

Precipitation in the east-central Sierra Nevada Mountains was acidic (pH of 3.7 to 4.9) during convective storms in the summer of 1981 (Melack and others, 1983). During this period, sulfate accounted for about twice as much acidity as did nitrate. Urban and agricultural sources within California are the supposed sources of the acidity. Over 90 percent of the precipitation was shown to occur as snow with a pH near 5.7, reflecting the chemistry of large frontal storms from the Pacific Ocean. This occurs even though the pH of these frontal storms is significantly lower (pH less than about 5) as they pass over cities and agricultural lands west of the study area which are potential sources of acidic anions. Thus, much of the acidity from urban and agricultural sources is removed before air masses cross the Sierra Nevada Mountains.

Trends in Surface-Water Acidification

Recent interest in possible acidification of surface water in the western half of North America has resulted in several studies of aquatic impacts and sensitivity. Broad-scale sensitivity maps indicate extensive areas in this region that should exhibit trends in aquatic chemistry in response to any sustained changes in precipitation chemistry (National Atmospheric Deposition Program, 1982; U.S. Environmental Protection Agency, 1983a).

At the Colorado site discussed by Lewis and Grant (1980), the rate of increase in hydrogen-ion loading to the Como Creek watershed was matched by an approximately equivalent decrease in stream transport of bicarbonate. The stream loadings of sulfate, nitrate, ammonia, and dissolved organic matter also showed significant increases during the study period. Total cation loading in the stream decreased enough to account for only about one-third of the observed decrease in alkalinity, indicating that much of the observed decrease in alkalinity was attributable to neutralization by hydrogen ion (Lewis and Grant, 1979).

In a 1979 reconnaissance of Colorado lakes sampled initially during the periods 1938–42 and 1949–52, there was a 17-percent decrease in alkalinity and a 0.2 unit decrease in pH. Both decreases were attributed to acidification of precipitation (Lewis, 1982). The author also attributes a 16-percent decline in "total residue" to acidification, with the mechanism being the removal of bicarbonate by strong acids. Although Lewis (1982) attempted to correct for seasonality and climatic variation, the method used may not have been appropriate. For example, if the correction for the 29-percent greater-than-average annual discharge were inadequate, bicarbonate and total residue would be expected to show approximately equal decreases due to simple dilution. More detailed chemical analysis would be necessary to determine whether bicarbonate has decreased disproportionately to other major constituents. The log-log plot of recent and former alkalinity (Lewis, 1982) indicates a seemingly constant percentage decrease in alkalinity between the two data sets, while acidification should cause a relatively greater percentage decrease in the alkalinity of the least-buffered samples. Methodology changes were estimated to produce an error or less than about 12 μeq/L, although the methyl-orange method is calculated to have a systematically greater alkalinity than the electrometric method of about 50 to 80 μeq/L (Kramer and Tessier, 1982). The average decrease in alkalinity of about 97 μeq/L compares to the 17 μeq/L free-acidity in precipitation at the Como Creek site (Lewis and Grant, 1979) if evapotranspiration of about 80 percent is assumed. Thus, although the data are compatible with the hypothesis that acidification of precipitation has caused the observed changes, other variables such as climate could also explain the changes.

At two reservoirs east of San Francisco, Calif., decreases in pH and alkalinity have occurred since about 1945 (McColl, 1981). The alkalinity decrease at Pardee Reservoir amounted to about 120 μeq/L between 1944–79. The author attributes the decrease to NO_x emissions from the highly developed San Francisco area, although lack of data on nitrate and sulfate concentrations in the reservoirs prevented direct evaluation of the issues.

In a 1981 reconnaissance of lakes in the Cascade Mountains of central Washington, acidification status was estimated by comparing calcium to bicarbonate (Henriksen, 1979). Lake alkalinities were found to be low (4 to 190 μeq/L), although no evidence of acidification was found (Logan and others, 1982).

A reconnaissance of lakes in the east-central Sierra Nevada Mountains during the summer of 1981 showed the lakes to be sensitive to acidification; however, a lack of historical data prevented evaluation of any trends in their chemistry (Melack and others, 1983).

On a regional basis, stream chemistry data are available in the West for 30 stations of the Hydrologic Bench-Mark Network. Trend analysis testing of the data showed a mixed regional picture for pH, but a general regional pattern of decreasing alkalinity and increasing sulfate (Smith and Alexander, 1983). As would be expected, the downward trends in alkalinity were most prevalent among stations with relatively low mean alkalinity. The Bench-Mark Network results are consistent with an increase in acid deposition in the West over a period of about the last 15 years.

DISCUSSION

From the information presented in the Results section of this report, it is apparent that differences exist in both the status of acidification and in the presence or absence of recent temporal trends among the geographic regions considered. Most of the controversy in the literature reflects alternative hypotheses to explain an inadequate historical data base, rather than criticism of inadequate or biased work. As a result, the following questions can be addressed by the cited literature:

1. Are temporal trends in acidification of precipitation evidenced? If so, is this a continental-scale, regional, or local phenomenon?
2. Are temporal trends in acidification of surface water evidenced? If so, is the same geographic distribution in item 1 applicable to changes in surface-water chemistry?
3. Are there apparent conflicts in trends of acidification of precipitation relative to acidification of surface water?

As presented in the regional sections on trends in precipitation acidification, the hypothesis of an increase in precipitation acidity in the Northeastern United States has been advanced, tested, and found to be substantiated by several studies, for which there are two main claims:

1. The precipitation is more acidic than it would be in the absence of anthropogenic emissions.
2. The area of greatest acidification of precipitation has rapidly expanded to the Southeast and Midwest during the last few decades.

Of these two claims, the first is readily validated by the information presented previously in this report. The evidence consists primarily of:

1. The measured acidity of precipitation relative to that (a) found in precipitation in remote parts of the world, and (b) predicted on the basis of natural geochemical cycles of strong acids; and
2. The comparison of precipitation chemistry from stations operated in the 1960's and 1970's to synoptic data from the mid-1950's.

The second claim is less readily addressed by the available data. Evaluation of the hypothesis of recent expansion of acidification to the Southeast is complicated by meager data. Present data from both individual researchers and national monitoring networks indicate acidity levels, from the Carolinas to Florida and westward into Alabama and Georgia, that are more acidic than would be expected for sites unaffected by anthropogenic emissions. In addition, comparison of these data with the meager historical data suggests, but does not unambiguously prove, increased acidification since the 1950's.

Evaluation of the hypothesis of recent expansion of acidification to the Midwest is severely complicated by the effects of climatic fluctuation on the only historical data. It is unclear whether the data are capable of providing an unambiguous test of the hypothesis.

Although definitive data do not exist to address the timing of acidification of precipitation in the Midwest and Southeast, data are available to examine trends in the Northeast since about the mid-1960's. These data indicate no significant change in precipitation acidity in the most acidified section of this region. Decreases in sulfate and increases in nitrate concentrations are well documented during the same time period. With respect to the initial acidification of the Northeast, the available data indicate this occurred before the mid-1950's; however, no unambiguous documentation has been presented to refine the estimate of acidification status prior to this period. It is difficult to estimate the reliability of data previous to the mid-1950's because of problems with inappropriate methodology and inadequate analysis schemes. The few data prior to the mid-1950's tend to address agricultural needs and provide little documentation on reliability.

In the Western United States, the level of precipitation acidity or the results of very short-term trend estimates indicate that individual sites have probably been acidified by anthropogenic emissions. Acidification noted by several studies (Lewis and Grant, 1980; Liljestrand and Morgan, 1979; Logan and others, 1982) generally has been attributable to localized sources, even though the sites seem remote. The time of initial acidification is not defined by these studies.

The hypothesis of an increase in the acidity of surface water has been advanced and, to some extent, tested. However, the degree of examination of alternative hypotheses has not advanced to the level achieved for precipitation chemistry.

In Canada, the best documented cases of acidification are lakes for which the acidification is attributable to local emissions. However, published information on a few lakes indicates that acidification since the mid-1960's may be attributed to regional sources (Dillon and others, 1978). Several rivers in Atlantic Canada exhibit recent declines in pH, although no consistent trends in sulfate concentrations exist for these rivers (Clair and Whitfield, 1983). While published trend information on precipitation acidity in this section of Canada is seemingly unavailable, trend information at nearby sites in the United States indicates no trend in acidity during this period (Likens and others, 1980; Peters and others, 1982).

Decreases in pH and alkalinity of lakes in New England and New York are well documented to have occurred sometime between the 1930's and the 1970's (Davis and others, 1978; Norton and others, 1981; Burns and others, 1981; Schofield, 1976; Pfeiffer and Festa, 1980). Hydrologic Bench-Mark data, collected beginning in the mid- to late 1960's, show a general pattern in the Northeast of increases in alkalinity and decreases in sulfate. In streams of New York State, acidification trends appear to be negligible for the period from the mid-1960's to the mid-1970's, and sulfate concentrations decreased (Peters and others, 1982).

In New Jersey, trend tests on data from a Hydrologic Bench-Mark station showed an increase in stream acidity for the period of 1963 through 1978 (Johnson, 1979), but the absence of a trend in pH for the period of 1973 through 1981 (Smith and Alexander, 1983).

The available information well documents a trend in surface-water acidification attributable to precipitation acidification in the Northeastern United States and Southeastern Canada. The Canadian sites mostly experienced acidification due to local sources. In the Northeastern United States, regional changes in precipitation chemistry apparently acidified lakes and streams in New England, New York, and New Jersey. The acidification appears to have occurred before the mid- to late 1960's, because data collected continuously since that time shows a lack of further acidification in New York streams (Peters and others, 1982), and a slight recovery of some acidified streams in scattered locations throughout the Northeast. The findings of these stream chemistry studies are consistent with a region-wide decrease in SO_2 emissions in the Northeast for the period 1965–1980 (Smith and Alexander, 1983).

In the Southeastern United States, most data on acidification of surface waters are ambiguous. An increase in sulfate has been documented in the Neuse River of North Carolina (Harned, 1982). Unfortunately, changes in pH and alkalinity of surface waters in North Carolina (Burns and others, 1981) give ambiguous results because of uncertainty in the effect of methodology on the value of historical data (Kramer and Tessier, 1982). Undocumented claims of acidification of Florida lakes have been published (Crisman and others, 1980).

In the West, most reports on the acidification of surface waters have reflected local conditions. A stream east of the Continental Divide, near Boulder, Colorado, has shown a decrease in alkalinity loading equivalent to the increase in hydrogen-ion loading from precipitation (Lewis and Grant, 1979). The source of acidity in the precipitation is estimated to be the local urban sources (Huebert and others, 1983). Ambiguous data indicate a decrease in alkalinity of lakes in the same general region of Colorado (Lewis, 1982). Two California reservoirs which receive precipitation influenced by local urban sources have been acidified (McColl, 1981).

In contrast to the earlier reports, the recently published work based on the Hydrologic Bench-Mark Network indicates regional trends in the chemistry of streams in the Southeast and the West. This report (Smith and Alexander, 1983) indicates that sulfate concentrations have increased in streams in both the Southeast and the West during the period since about the mid-1960's (fig. 4a). In both regions, there have been concurrent decreases in

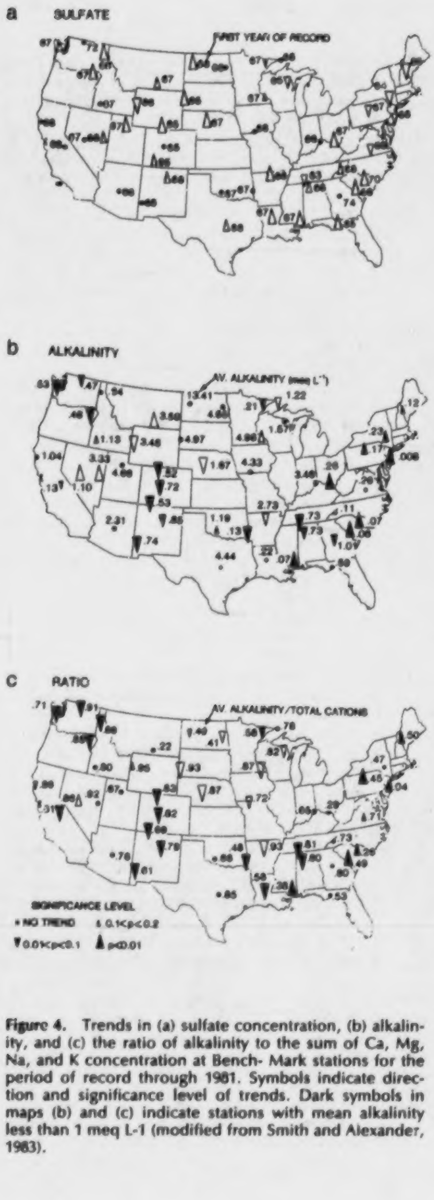

Figure 4. Trends in (a) sulfate concentration, (b) alkalinity, and (c) the ratio of alkalinity to the sum of Ca, Mg, Na, and K concentration at Bench- Mark stations for the period of record through 1981. Symbols indicate direction and significance level of trends. Dark symbols in maps (b) and (c) indicate stations with mean alkalinity less than 1 meq L-1 (modified from Smith and Alexander, 1983).

alkalinity (fig. 4b) and in the ratio of alkalinity to the sum of the major cations (fig. 4c). These chemical changes are consistent with the initiation of acidification in bicarbonate systems. In the Southeast, the meager data on precipitation chemistry suggest a regional pattern of recent acidification. However, the Bench-Mark Network results are the first indication of the possible regional acidification of surface waters. In the West, precipitation-chemistry data are unavailable for most of the region for the time period in question. Thus, although the Bench-Mark data suggest that regional acidification of surface waters may be occuring in the West, precipitation data are needed to test the hypothesis.

CONSIDERATIONS FOR FUTURE ACID-PRECIPITATION NETWORKS

It is apparent from the discussion presented in this report that data limitations have been a major constraint in developing an understanding of the acidification of precipitation and surface water. The lack of trend information for surface-water systems in much of the country does not reflect a complete absence of data, but rather a lack of data on appropriate systems and chemical analysis by inconsistent methodologies. The period since the mid-1960's has been one of great increase in collection of both synoptic and repetitive data on the chemistry of surface water. Documentation of changes attributable to precipitation during this period, however, is limited to a relatively few studies by individual researchers and data from a 47-station nationwide network designed to detect changes in systems remote from local anthropogenic influences. Further data limitations result from a failure to examine the hydrologic system in its entirety; that is, concurrent precipitation and surface-water data generally are not available. Moreover, ground-water systems and process-oriented research have been ignored in most studies examined by this report.

The concept of the integral nature of hydrologic systems and the futility of examination of segments as self-sufficient systems is not new, but unfortunately, is neglected. This neglect has been largely influenced by the design of data-collection networks and individual studies to address the specific requirements of legislation. The period of great increase in chemical monitoring since the 1960's has seen these specific legislative requirements change from conventional sanitary indexes, to toxic metals, to toxic organic compounds in pace with control efforts and progress in analytical chemistry. Without doubt, there is need to address limited questions regarding compliance with legislation designed to protect both aquatic life and the general welfare. Unfortunately, the concentration of effort to address only these specific requirements has seriously hampered our understanding of what constituent concentrations might be expected to occur naturally, and what temporal and spatial distributions we should see in the absence of anthropogenic sources. Only well-planned commitments to define natural controlling mechanisms in hydrologic systems will allow future problems to be addressed with an adequate historic data base. Recent reports on the effects of man on acidification at remote sites indicate that this commitment is needed soon and that site selection is much more difficult than previously has been supposed.

SUMMARY

The acidity of precipitation in the Northeastern United States and Southeastern Canada has increased in the past, probably as a result of anthropogenic emissions. The increase in New England and New York occurred primarily before the mid-1950's. Since the mid-1960's there has been no significant change in the acidity of precipitation in this region; however, sulfate concentrations have decreased and nitrate concentrations may have increased. The time of initial acidification in Southeastern Canada is not known because of a lack of historical data. In the Southeastern United States, the evaluation of whether precipitation has been acidified is complicated by meager data. The available data show that precipitation is more acidic than would be expected for sites unaffected by anthropogenic emissions. In addition, comparison of recent data with the meager historical data suggests, but does not unambiguously prove, increased acidification since the 1950's. In the Western United States, available data indicate that precipitation at individual sites has been acidified by anthropogenic emissions. The acidification generally has been attributable to localized sources and the time of initial acidification is undefined.

Acidification of lakes and streams in the Northeastern United States has occurred in a time frame compatible with the hypothesis that acidification of precipitation was the cause. The acidification of surface waters appears to have occurred before the mid- to late 1960's. In Southeastern Canada, the best-documented cases of acidified lakes point to localized sources of acidic emissions as the cause. Sparse evidence of recent regional acidification of lakes and streams exists, but evidence for acidification of precipitation as the cause is largely lacking. In the Southeastern United States, most data on acidification of surface waters are ambiguous, and in the West, most of the data reflect local conditions. However, recent analysis of a national network of remote stream sampling stations indicates that, since the mid- to late 1960's, sulfate concentrations have increased in the Southeast and the West, with a concurrent decrease in alkalinity. Additional work is needed to test the hypothesis that regional acidification of surface waters is occuring in the Southeastern and Western United States.

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☆ U.S. GOVERNMENT PRINTING OFFICE: [illegible]

DEC
PUBLICATION

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by
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August 1980

New York State/Department of Environmental Conservation

[illegible]

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Abstract

Many surface waters in the Adirondack region of New York State have low alkalinities due to a carbonate-poor geology. This condition makes these waters particularly sensitive to the high acid ion deposition associated with the region's airshed.

Since 1975, pH and alkalinity measurements have been made on 849 ponded waters throughout the Adirondack region to determine the scope of water quality impacts associated with acid ion deposition and to provide a baseline inventory for indexing future measurements. The present condition of surface waters is described on the basis of summertime, one meter depth, pH measurements obtained with a pH meter under air-CO_2-equilibrium conditions. Twenty-five percent of the waters in the survey registered pH readings below 5.0. These waters comprise 10,460 surface acres.

Comparisons of historic and post-1974 acidities are made where data points from comparable methodologies exist. Relationships between meter pH, colorimetric pH, alkalinity, conductivity, calcium, lake surface area, lake surface elevation and geographical location are discussed. Changes in fish species composition and sportfishing yields observed in waters exhibiting increased acidity are reviewed.

Description of Adirondack Lake and Pond Resources

As a result of extensive glacial activity, the Adirondack region of northeastern New York State contains a vast and varied ponded water resource. The most recent count adapted from a 1979 inventory of the Adirondack ecological zone (Pfeiffer 1979) reveals that there are approximately 2,877 individual lakes and ponds, encompassing some 282,154 surface acres. The New York State portion of Lake Champlain, 97,000 acres, is purposely excluded from this summary since its low elevation waters are not considered to be representative of the Adirondack uplands. Average size of ponded waters included in this inventory approaches 98 acres and ranges from those of less than one acre to 28,000 acre Lake George. Figure 1 delineates the boundaries of the Adirondack ecological zone in northern New York State. This zone perimeter is derived from a modified 1,000 foot elevation contour but includes Lake George and Sacandaga Reservoir. Appendix Figure 2 depicts the Adirondack region overlain with 15 minute U.S.G.S. quadrangle map outlines.

Wilderness Concepts and Types of Fisheries

In comparison to other areas of New York State and the northeast, the Adirondack Mountain region (Figures 1-3) is relatively undeveloped and sparsely settled by permanent residents. Article XIV, Section I of the New York Constitution is intended to protect the quality of waters within the forest preserve. More recently, the State and private land use constraints imposed by the State Land Master Plan and Land Use and Development Plan are designed to further maintain the wilderness character of the Adirondack Park. As a result, much of the Adirondack water resource is eminently qualified to provide the requisite scenery, solitude and preferred fish for a "quality" wilderness fishing experience. To many an urban resident, this chance to participate in and enjoy his or her sport in relative isolation is the prime attraction which sets the Adirondacks and its fisheries resources apart. Also, the great number and variety of available waters permit a wide spectrum of diversity and choice in angling opportunities.

For purposes of program administration, the fish management activities in New York State have been broken down into several subprogram areas which represent "classes" of waters and describe types of fisheries. The "classes" of ponded waters having direct relevance to the Adirondack scene are listed by frequency and acreage in Table I. One of the most characteristic and numerous types of ponded waters encountered in the Adirondacks is brook trout ponds. In the recent past, this "class" of waters has been the one most affected by acidification. Many of these waters are small headwater ponds located at high elevations. It is ironic that many of these remote wilderness waters which have been so well protected from conventional sources of pollution have, due to their location, become the victims of atmospheric acidification.

Other types of fisheries represented by the five remaining "classes" of waters include two-story lakes, coldwater ponds, warmwater lakes, unknown (unclassified) ponds and acidified ponds (Pfeiffer op. cit.). Unknown (unclassified) ponds are Adirondack waters which could not be assigned to one of the preceding "classes" due to a paucity or complete lack of survey information. Similar to brook trout ponds, many of these unknown ponds also lie at relatively high elevations and, thus, are presumed susceptible to acidification. To date, and including some naturally acid "bog" type waters, we have identified 264 Adirondack ponded waters, representing about 11,518 acres, which register summer surface pH values below 5.0 and are no longer considered capable of supporting viable fisheries. Most of them are vulnerable, former brook trout ponds. A cut-off point which considers waters having a summer surface pH below 5.0 is a somewhat arbitrary measure of "critical" acidification status. However, in our experience, this breakpoint appears to coincide fairly well with losses of even the more acid-tolerant fish species, such as brook trout.

Geology and Environmental Limitations

In terms of bedrock geology, the Adirondacks are the southernmost extension of the vast pre-Cambrian shield. The soils are predominantly shallow, stony and relatively infertile. Most of the surface waters exhibit low alkalinities and pH values which fall in the acid range of the pH scale. These conditions reflect the dominance of well weathered metamorphic and igneous rocks, represented by gabbro, syenite, anorthosite, gneisses and schists. Limited outcrops of calcite marble provide localized oases of fertility in this generally unproductive environment. The Adirondacks are also unique in that they exhibit specific historical, physical, chemical and biological characteristics which diverge widely from other physiographic regions of New York State. Along with obvious differences in bedrock geology, as illustrated in Figure 4, accompanying infertile soils, low solar radiation and a relatively short frost-free period, the nutrient-poor Adirondack waters exhibit low natural ion content. Values for calcium (Appendix 1), magnesium and bicarbonate are particularly depressed and account for the soft waters which characterize the aquatic environments. These factors contribute to the poorly buffered condition of many Adirondack waters which makes them particularly vulnerable to acidification. This susceptibility is compounded by their heavy annual precipitation load and downwind location from significant sources of air pollution.

Background of Lake Acidification Studies in the Adirondack Region of New York State

As recently as ten years ago, there were probably only a handful of atmospheric scientists and ecologists in New York State who were even aware of the acid precipitation problem. However, by the mid-seventies there was a veritable literature explosion on this subject, accompanied by greatly expanded research and inventory efforts by fisheries-oriented investigators. Admittedly, some Adirondack fisheries workers were aware of acidification and associated losses of fish populations in the early 1950s but the relationship to atmospheric pollution was not widely established until Scandinavian and Canadian-based literature demonstrated the connection.

A milestone in Adirondack lake and pond acidification studies was placed in the early summer of 1975. Dr. Carl Schofield of Cornell University, in cooperation with Regional DEC fisheries staff, undertook a comprehensive water chemistry and fish survey of 214 high elevation ponds (Schofield 1977). This project was largely financed by Dingell-Johnson funds and was limited to waters of 2,000 foot elevation or more. The survey indicated that fifty-two percent of the waters sampled exhibited surface equilibrium pH levels below 5.0 and only seven percent were in the pH range 5.5-6.0, which corresponds to the area of minimal buffer intensity and acid neutralizing capacity. It was suggested that the acid conditions observed in many Adirondack lakes logically resulted from atmospheric acid loading with sulfate representing the major anion present. Elevated concentrations of aluminum, manganese and zinc were also found in acidified lakes and increased concentrations of these metal ions, at low pH, were suspected of synergistic increases in toxicity. Additional research conducted by Dr. Carl Schofield in 1974, 1975 and 1976 revealed the role of increased atmospheric deposition of nitrate as well as the occurrences of brief, but severe, pH depressions associated with episodes of snowmelt.

While New York State helped pioneer the biological survey concept in the 1920s, the acidification crisis of the 1970s pointed out the relative paucity and poor quality of some of the historic and recent survey data in respect to standardized chemical techniques for determining pH and alkalinity. The original biological survey pH methodology, employed from 1926 to 1939, utilized the Hellige color comparitor but only a fraction of the waters in each watershed were actually analyzed. Similarly, the methyl-orange methodology was employed for alkalinity determinations but, again, only a percentage of waters in each watershed were actually sampled. Following World War II, State fisheries personnel were also equipped with either field or laboratory electronic pH meters but the exact test procedures employed were rarely recorded. Field pH meters were frequently subject to breakage or malfunction and even recent models have proven unreliable under rigorous field conditions. With the advent of the "Hach" kit, many units abandoned their fragile field pH meters and again resorted to the less accurate colorimetric technique. "Hach" alkalinity kits gradually replaced the methyl-orange, phenolphthalein methodology but, in many instances, alkalinity measurements were simply not taken.

In light of the growing awareness of the acidification problem and the need for more standardized techniques in the mid-seventies, Dr. Carl Schofield began drafting detailed guidelines for survey and monitoring acid-sensitive waters in New York State (Schofield 1978). They outlined standard operating procedures for detection of trends in water quality and fish population status.

Summary of Post-1974 pH-Alkalinity Measurements and Relationships

The year 1975 was selected as the cut-off point for describing current Adirondack lake acidity status referred to in this report. With the ongoing acidification problem, it was felt that older data might be too stale for describing current conditions and the 1975 comprehensive survey produced the first large up-to-date data base founded on accepted procedures for determinations of pH, alkalinity and conductivity. Regional DEC fisheries crews have also been operating under similar guidelines in connection with comprehensive fish and water chemistry surveys and long-term monitoring waters surveys, since 1975. Another significant source of contemporary water chemistry data resulted from an Indiana University project conducted by Don Charles in the summer of 1978, when some 50 geographically diverse Adirondack ponded waters were sampled. The Bureau of Fisheries Lake Acidification Studies Unit, formed in 1979, conducted an extensive water chemistry survey of 396 waters via helicopter in that summer.

Chemical analyses for the 1979 extensive survey were completed at the DEC laboratory in Ray Brook. Results are reported as the mean of duplicate pH determinations run under air-CO_2-equilibrium conditions achieved by aeration of the samples via an air pump and gas dispersion tube. Similarly, duplicate acid titrations were run for alkalinity determinations with the sample under continuous aeration. Each sample was titrated in a step-wise fashion by adding increments of 0.1N hydrochloric acid from a calibrated piston transfer pipette with disposable polypropylene tips. The sample was allowed to reattain pH equilibrium after each increment of acid was added and the pH was then recorded down to the titration of pH 3.5. Alkalinity was determined by regression of Grans plot titration pH's and cumulative acid volumes. Procedures for pH and alkalinity determinations are outlined in Appendix II.

Summer surface (1 meter depth) pH values encountered in the 849 Adirondack waters surveyed between 1975 and 1979 are summarized by 0.1 pH unit groups in Figure 5. These ranged from a low of 3.5 to a high of 10.0 with the mean hydrogen ion concentration corresponding to pH 4.93. Since the logarithmic basis for the pH scale greatly accentuates low values, it may be more reassuring to weight this calculation on the basis of actual acreages involved and derive a more representative mean hydrogen ion concentration corresponding to pH 5.48. We have adopted a pond acidification status classification which considers waters exhibiting a summer surface pH above 6.0 as being in a satisfactory condition. Those exhibiting a summer surface pH between 5.0 and 6.0 are considered "endangered" while those demonstrating readings below 5.0 are declared to be in a "critical" state of acidification. Figure 6 describes the acidity status, by acreage, of the Adirondack ponded water resources based on post-1974 measurements. Obviously, this rating system is somewhat simplistic since other factors, such as dissolved metals toxicity, episodes of snowmelt pH depression and the effects of biological activity and recent rainstorms, all compound the picture. Nevertheless, we feel that this type of grouping does provide us with an estimate of acidification status, consistent with observed fish distribution, which can serve as a crude baseline to detect future trends. Results of the 1975-1979 summer surface pH data summaries shown in Table II indicate that 25 percent of the numbers and almost five percent of the acreage of waters sampled were at the "critical" level. This emphasizes the fact that most of impacted waters are relatively small.

This phenomenon is more clearly depicted in Figure 7 where lake surface area increments are matched against percent acreages within pH ranges. The highest percentage of "critical" pH values is found among smaller waters. The inverse relationship between the surface acreage of Adirondack ponded waters and their vulnerability to "critical" acidification is related to the headwater location of many of these smaller ponds.

A distinct positive relationship was observed between lake surface elevation and "critical" pH readings for the 1975-1979 survey sample.

This phenomenon is illustrated in Figure 8 where lake elevation ranges are matched against percentages of area within pH ranges. The higher elevation waters demonstrate the highest percentage of critical pH values. The positive correlation between increased elevation and reduced pH logically reflects the combined influence of heavier precipitation load, the smaller surface acreage and watershed size, which characterizes most headwater ponds, and the prevalence of granitic bedrock and shallow soil deposits.

Severity of the lake acidification problem varies considerably within the Adirondacks. The geographical distribution of impact, by 15' U.S.G.S. quadrangles, is illustrated in Figure 9. The pH ranges encountered in the acreage of water sampled in each quadrangle during the 1975-1979 time-frame are depicted in individual pie charts. Although the distribution and intensity of sampling varied between quadrangles, problem areas in the west-central and southwest regions are readily discernible. On the other hand, the eastern perimeter of the Adirondack region is much less impacted. Differences in annual precipitation levels (Figure 10) appear to exert a substantial influence on the geographical distribution of impact within the Adirondack region.

Some acid rain researchers think that alkalinity determinations are a better indicator of lake acidification status than pH, particularly when the Gran titration technique is employed to obtain the former parameter. One of the problems associated with pH determinations relates to the influence of primary production on diurnal CO_2 levels. Also, single surface samples may not be representative of the entire water column. They are generally higher, unless influenced by a recent rainstorm, in which case they may be significantly lower. Nevertheless, we purposely selected broad pH ranges to categorize acidification status because of the relative paucity of historic alkalinity data. In addition, our current analysis results indicate a generally good correlation between these two parameters for daytime, summer, surface readings under air equilibrium conditions (Figure 11). To adjust for the potential variability in pH readings, we have adopted the concept of using broad ranges rather than emphasizing precise individual values in classifying waters.

Figure 12 illustrates three categories of total alkalinities encountered in the 1975-1979 time-frame sampling effort. These ranged from a low of -109.9 to a high of 1,132.3 ueq/l with a mean value approaching 131.1. However, when this calculation is weighted on the basis of acreages within alkalinity ranges, the mean is elevated to 168.7 ueq/l. For Adirondack conditions, we have adopted a total alkalinity value of 10 ueq/l as the cut-off point below which "critical" acidification is interpreted from summer surface (1 meter depth) alkalinity measurements. The category ranging from 11 to 50 ueq/l corresponds with the "endangered" fraction while values in excess of 50 are considered to be "satisfactory".

Figures 13-15 portray relationships between total calcium and alkalinity, total Ca-pH and pH-conductivity. These illustrate regressions derived from a 1979 survey sub-sample of 100 Adirondack lakes.

As expected, there is a close correlation between calcium concentrations and total alkalinity with zero or negative alkalinity values generally occurring when total calcium levels fall below 2 mg/l. Likewise, pH values of less than 5.0 are generally associated with total calcium concentrations below 2 mg/l. On the regression curve developed for 100, 1979 samples, pH 5.0 corresponds with calcium concentration of 1.62 mg/l and pH 6.0 with a concentration of 3.72 mg/l.

The relationship between pH and conductivity was not as strong. Waters exhibiting conductivities between 20 and 30 mmho/cm had pH values ranging from less than 4.0 to above 6.5 units.

In general, waters which have been lost to fish production can be characterized as having a pH below 5.0, total alkalinity below 10 ueq/l, conductivity below 40 mmho/cm and calcium concentrations below 2 mg/l. Lakes and ponds exhibiting pH below 6.0 had alkalinities of less than 50 ueq/l and calcium concentrations below 4 mg/l.

The relationship between mean equilibrium laboratory meter pH values and laboratory colorimetric pH readings for a set of 1979 samples is presented in Figure 16. Within the acid range, the colorimetric (Hellige comparitor) readings were consistently higher than the meter determinations. This disparity is most pronounced at the lower end of the pH scale and helps confirm a long-standing opinion that the colorimetric methodology is biased in favor of elevated readings which are most widely divergent in waters which lack buffering capacity.

The relationship between historic colorimetric (Hellige comparitor) and current colorimetric pH readings is presented in Figure 17 where pH distributions are compared for waters in the 1979 sub-sample for which historic data were available. Historic readings obtained in the 1930s were generally higher than comparable current determinations for the same group of waters. This reflects a general deterioration of water quality during the 40-year time frame between samplings. Today, using the identical Hellige colorimetric pH methodology, we have many more readings below 6.0 than were encountered in the 1930s. Figures 18-20 also illustrate the shift in Hellige pH distribution observed from the 1930s to 1979 for a sub-sample of Adirondack waters. Again, there are more waters in the lower pH ranges today.

Impact on Fisheries

As indicated previously, acidification effects related to atmospheric pollution have exerted the greatest negative impact on former Adirondack brook trout ponds. This is not because brook trout are particularly sensitive but rather because they were frequently the only game fish species resident in many vulnerable, small, high elevation habitats. Schofield's 1975 comprehensive water chemistry and fish survey, (Schofield op. cit.) limited to high elevation waters over 2,000 feet, revealed that 82 percent of 111 waters exhibiting a surface pH of less than 5.0 were devoid of fish life. Current resource inventory estimates indicate that at least 180 former Adirondack brook trout ponds, representing some 7,130 acres, have succumbed. Due to an ongoing modest liming program, about 672 acres within the acidified category are currently viable but would undoubtedly revert to their acidified status if periodic lime treatments were terminated. Despite liming efforts, the prognosis for the immediate future does not appear very optimistic and ongoing atmospheric acidification will undoubtedly continue to plague this resource.

One hopeful element relates to the recent (post-1977) substitution of more acid-tolerant Temiscamie x domestic brook trout hybrids, and/or their backcrosses, in routine fall fingerling pond stocking programs. The possibility that this superior hybrid may be providing some immediate benefits is borne out in the case history of Spruce Lake. Fish populations in this remote body of water have been checked periodically since 1934 and a variety of native fish species were encountered up to 1976. These included brook trout, lake trout, white sucker and golden shiner. Very recently, some "critical" pH readings have been documented and a 1979 gill-netting survey collected only brook trout. These fish, however, included at least three age classes with excellent representation among the youngest age group. A marking program has been initiated to positively substantiate the contribution of hybrid plantings. The fish survey record for South Lake also demonstrates a progressive loss of resident native fish species which appears to be symptomatic of the acidification phenomenon. This water is even more severely impacted than Spruce Lake and past plantings with several pure wild strain and one hybrid strain of brook trout failed to maintain a viable fishery. Case histories for South, Spruce and several other impacted waters are provided in Appendix III.

Comprehensive fish surveys conducted in 1979 sampled a total of 52 waters. Unlike the aforementioned 1975 survey, these waters were not limited to 2,000 foot, and over, elevations. Sampling was accomplished via Swedish nylon multifilament gill nets and minnow traps. The choice of sampled waters was not based on a randomized selection process and the results obtained do not, in themselves, describe the overall relationship of fish presence in respect to pH ranges. They do correlate well, however, with previous findings and provide an example supporting the acidification classification scheme we are employing.

Results were that 46 (88%) of the test-netted waters contained at least one species of fish. These waters exhibited summer surface pH readings ranging from 4.81 to 7.00 but, in the case of the lowest reading, only a single brook trout specimen was recovered from a springhole. Conversely, six (12%) of the sampled waters did not yield any fish life and their surface pH readings ranged from an extreme low of 3.54 to a high of 6.00.

When fish recovery data is matched against pH ranges, we find that three waters (6%) of the total sample exhibited surface pH values below 5.00 and only one of these waters yielded fish life in the form of a single brook trout specimen. In the intermediate pH range, between 5.00 and 6.00, there were 24 waters, 46 percent of the sample, and 86 percent of these contained at least one species of fish. All of the 25 waters, 48 percent of the sample, exhibiting pH values above 6.00 contained fish life.

Among the 46 waters supporting some type of fish life, 41 (89%) contained one or more species of coldwater game fish. Brook trout were collected in 40 waters, lake trout in three, rainbow trout in three and brown trout, splake, landlocked Atlantic salmon and kokanee, each in a single water. Three waters (7%) contained a warmwater game fish in the form of smallmouth bass. Among the latter, one water was in the intermediate pH range while two waters were in the range above 6.00.

Canadian researchers (Beamish et al. 1975) have documented the fact that several warmwater fish species, including smallmouth bass and walleye, are particularly intolerant of acidification and noted reproductive failure. Table III shows where some warmwater fish species losses are expected to occur in respect to the pH scale. In the Adirondack region, a number of former bass lakes, including Woodhull Lake, Big Moose Lake and Canada Lake have lost their smallmouth populations in the recent past and reproductive failure associated with increased acidity is suspect. Similarly, several other marginal pH bass waters, including Cranberry Lake and Tupper Lake, appear to be suffering marked population declines.

Of the waters exhibiting pH below 5.00 in the 1979 extensive water chemistry survey, about 23 percent by number and 33 percent by acreage represented potential losses of warmwater fisheries. This is probably a minimal estimate where sensitive species such as black bass and walleye are involved. Thus, while our initial concern with the acidification problem emphasized the loss of Adirondack brook trout ponds, it appears that vulnerable warmwater habitats and food chains are also being lost or endangered.

Sportfishing yields in several impacted waters have been eliminated and presumably reduced in marginal waters where sensitive species occur. Comprehensive Plan for Fish Resource Management Within the Adirondack Zone, Pfeiffer (op. cit.) estimated an overall average yield for Adirondack ponded waters approaching five pounds/acre/year. Our latest updated resource inventory determined that nearly 11,000 acres of water have reached the "critical" state of acidification. Since much of this acreage represents remote former brook trout ponds, it is considered likely that both angling pressure and resulting yields would have been considerably below the Adirondack Zone average and a reduced yield expectancy of two pounds/acre/year is postulated. This exercise generates an estimated loss in yield of some 22,000 pounds per year which can be attributed to atmospheric acidification. Spin-offs associated with this decline logically include loss of recreational opportunity as well as negative impacts on the ecology and economy of the area.

Recommendations and Information Needs

In response to the acidification dilemma, the Bureau of Fisheries of the NYS Department of Environmental Conservation has embarked on an acid waters management program which includes the following elements:

1. Long-term monitoring waters surveys, both winter and summer (six study lakes).
2. Computerization of existing and updated lakes and pond survey data.
3. Mapping of waters by their state of acidification.
4. Comprehensive fish and water chemistry surveys (60 waters in 1980).
5. Extensive water chemistry surveys (100 ponded waters and 600 stream stations on 160 streams in 1980).
6. Pond liming (at least 3 to 6 waters).
7. Refuge liming research under contract to Cornell University.
8. Research on performance of acid-tolerant brook trout strains under contract to Cornell University.

Successful implementation will enhance our position to determine the true impact of surface water acidification on Adirondack aquatic resources and also develop or maintain short-term mitigative measures to help combat this insidious threat. The latter includes continuation of both routine and experimental liming programs to assist in answering the information needs: "Under what conditions is liming an economically defensible technique?" Similarly, continued interim production stocking of currently available, acid-tolerant brook trout strains and research on selective breeding for increased tolerance will help answer the question: "Can the stocking of acid-tolerant strain fish pay sufficient dividends in increased survival to justify the costs?" There is also a pressing need to address the problem of acid precipitation's effect on the mobilization of metals such as mercury, cadmium and aluminum.

A primary information need of the Bureau of Fisheries is to determine relative "breakpoint" models for maintaining various fish species and fish species associations in Adirondack waters. This information would be of immediate use in (1) interpreting observed changes in fish species composition; (2) predicting fish population impacts from water chemistry data thus leading to prioritization of future surveys; (3) identifying indicator species whose occurrence or loss may precede the collapse of sport fish populations; (4) adjusting stocking policies for salmonids, walleye and tiger muskellunge to avoid planting in unfavorable chemical situations; (5) better assessment of overall acid precipitation impacts on fish resources to help answer the question: "At what point in time can we expect to lose viable species-specific, fisheries from any given water?"

While considerable progress has been made toward describing the current chemical status of Adirondack waters, efforts to document the impact of increasing acidity on fish stocks have lagged due to manpower limitations. The labor intensive task of surveying lakes and ponds to determine population densities, species and age-class composition has fallen primarily on the already understaffed Regional DEC fisheries units. This situation has prohibited a current assessment of the overall status of a number of important fish species, especially warmwater species in many larger waters. For example, of 28 Adirondack waters historically containing walleye, only four have been surveyed since 1974. There is a need to field at least three more survey teams to bring this effort up to acceptable levels.

Obviously, the ultimate solution to the problem is out of the fisheries managers' domain and relates to the rapid development and employment of control technologies and acceptable energy alternatives on an international scale. There will be no solution without difficult political decisions stimulated by public interest and demand. Resource agencies, such as the Bureau of Fisheries, must provide facts and inform the public. We can only hope that an enlightened public will be responsive to stopping acidification in time.

ACKNOWLEDGEMENTS

Development and completion of this report would not have been possible without the cooperation and assistance of many individuals. Mr. Carl Parker, Chief of the Bureau of Fisheries and Dr. Paul Neth, Inland Fisheries Supervisor, provided helpful guidance and editing in developing the document. We are particularly indebted to the Technicians assigned to the Lake Acidification Studies staff, including: Mr. Robert Bonham, Mr. John Feurer, Mr. Vance Gilligan and Mr. Daniel Moore. Also included to this category is S.U.N.Y. Syracuse University intern Mr. Jeffrey McGrew and Syracuse University volunteer Mr. Alan Dingman. Regions 5 and 6 Regional Fisheries Managers, Mr. Leigh Blake and Mr. Gene Lane, and their respective staffs made a heavy contribution, especially Senior Fish and Wildlife Technician Mr. Raymond Brown and Senior Aquatic Biologist Mr. James Coutu. Conservation Biologist, Mr. Gerald Barnhart, was also most helpful. S.U.N.Y. Syracuse University intern Mr. Bernard Zahn was responsible for developing many of the Figures and Tables associated with this document as was Senior Draftsman, Mrs. Barbara Scouten. The Audio-Visual Unit in Albany, under the direction of Mr. Robert Rehbaum, prepared the final graphics. Mr. George Furman's assistance was essential in this task.

Our special thanks are directed at Dr. Carl Schofield, Senior Research Associate at Cornell University, for his very basic contributions, as well as Dr. Donald Charles, formerly of Indiana University, and Mr. David Johnson, formerly of the Adirondack Park Agency. Invaluable computer help was provided by the Survey and Inventory staff at Ray Brook, represented by Mr. Walter Kretser, Ms. Lois Klatt and Mrs. Anna Davis. Two Hale Creek Field Station staff members, Mr. Joseph Spodaryk and Mr. Ralph Karcher, contributed their expertise in chemical analysis and Mr. James Colquhoun of the Rome Laboratory also provided his input. Mr. Gerald Mikol of the Pure Waters Unit helped provide EPA funding for and supervision of two Technicians stationed at Ray Brook in connection with a Clean Lakes grant. Valuable historical information relating to the High Peaks Pond fisheries was derived from Mr. Vincent Engels published reminiscences. Thanks are also due to the Division of Aviation staff members who provided helicopter transportation for the field survey crews, especially Chief Pilots, Mr. Amsden Howland and Charles Wolfe. Last, but not least, we wish to commend the Central and Regional Office Stenographers who exercised patience in typing the numerous revisions and corrections associated with this report. We are particularly appreciative of the contribution of Ms. Jacquelyn Abrams, Ms. Judy O'Dell, Ms. Camille Rafferty and Mrs. Beatrice Levitch.

Table I. Inventory of Ponded Waters in the Adirondack Regions*, Depicting Types of Fisheries by Classes of Water

Classes of Waters	Number	Acres
Brock Trout Ponds	512	28,408
Two-Story Ponds and Lakes	65	102,163
Coldwater Ponds and Lakes	72	5,655
Warmwater Ponds and Lakes	437	112,869
Unknown (Unclassified) Ponds and Lakes	1,527	21,541
Total	2,613	270,636
Known Acidified Ponds and Lakes		
Limed Acid Ponds**	16	672
Known Naturally Acid Ponds***	36	386
Post 1974 Acidified Ponds	212	10,460
Total	264	11,518
Grand Total	2,877	282,154

*Modified from inventory of waters within the Adirondack Ecological Zone as originally described in: / "A Comprehensive Plan for Fish Resource Management Within the Adirondack Zone", August 1979.

**These waters are presently viable but would revert back to their acidified state if periodic lime treatments were terminated.

***Some Adirondack ponds were known to be acidic prior to recent surveys. Most are presumed to be "naturally" acid due to organic acids associated with bog shoreline areas.

Table II. Subsample of Adirondack Region Ponded Waters for Which Post-1974 Summer Surface Meter pH Data is Available, Showing pH Ranges

Acreage

pH Range	Acres	Percentage of Total Acres	Acidification Status
less than 5.00	10,460	4.7	critical
5.00-6.00	63,243	28.4	endangered
above 6.00	149,021	66.9	satisfactory
	222,724		

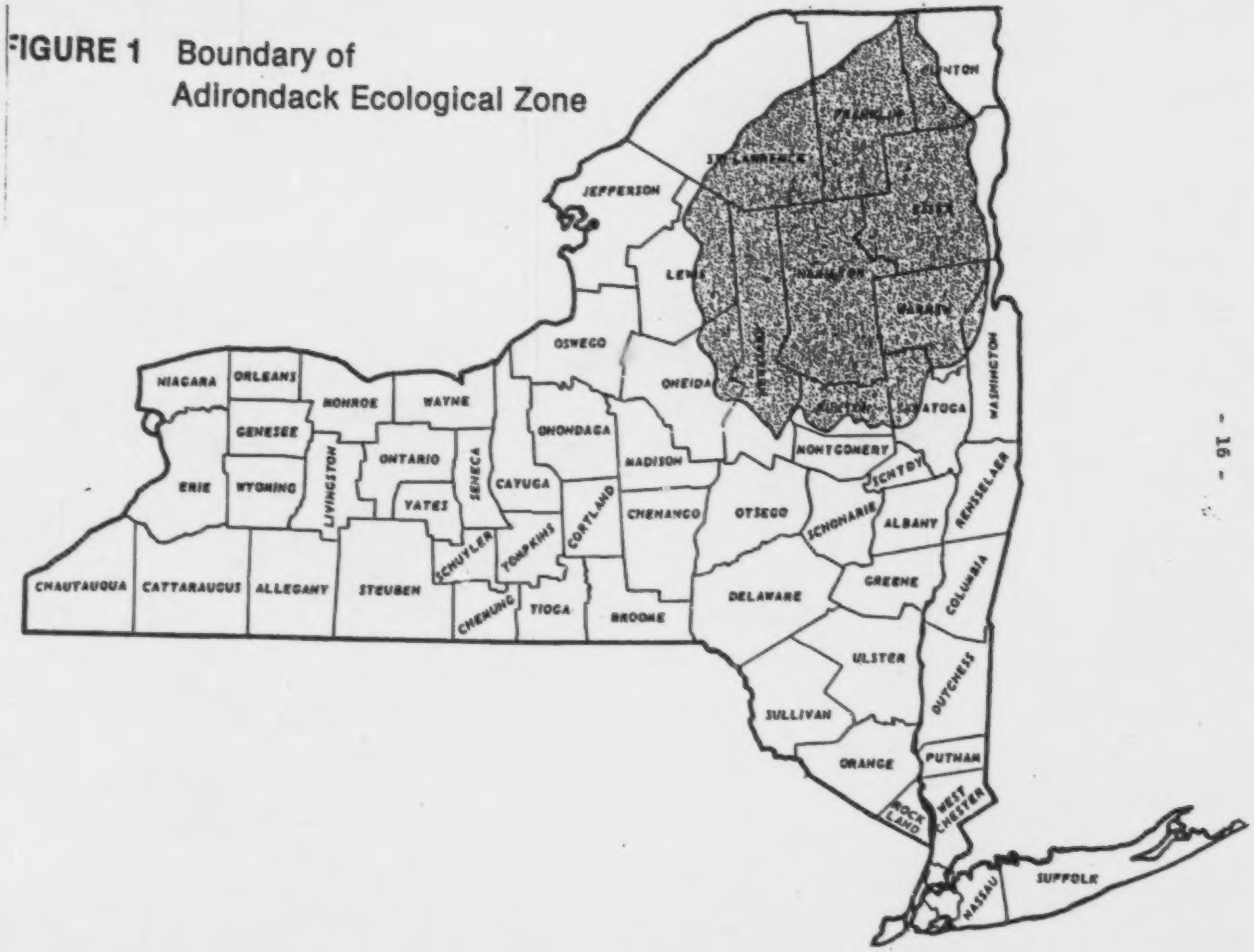
Number of Lakes and Ponds

pH Range	# of Waters	Percentage of Total # of Waters	Acidification Status
less than 5.00	212	25.0	critical
5.00-6.00	256	30.1	endangered
above 6.00	381	44.9	satisfactory
	849		

Table III. Approximate pH at which fish in the LaCloche Mountain Lakes (Ontario, Canada) stopped reproduction - Modified from Beamish 1976

pH Range	Species
6.0+ to 5.5	Smallmouth bass Walleye
5.5 to 5.2	Lake trout
5.2 to 4.7	Brown bullhead White sucker Rock bass
4.7 to 4.5	Lake herring Yellow perch Lake chub

FIGURE 1 Boundary of Adirondack Ecological Zone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LEWIS
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OSWEGO
ONEIDA
NIAGARA
ORLEANS
MONROE
WAYNE
ONONDAGA
MONTGOMERY
GENESEE
ONTARIO
SENECA
CAYUGA
MADISON
SCHTDY
ERIE
WYOMING
LIVINGSTON
YATES
CORTLAND
CHENANGO
OTSEGO
SCHOHARIE
ALBANY
RENSSELAER
SCHUYLER
TOMPKINS
CHAUTAUQUA
CATTARAUGUS
ALLEGANY
STEUBEN
CHEMUNG
TIOGA
BROOME
DELAWARE
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PUTNAM
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WEST CHESTER
NASSAU
SUFFOLK

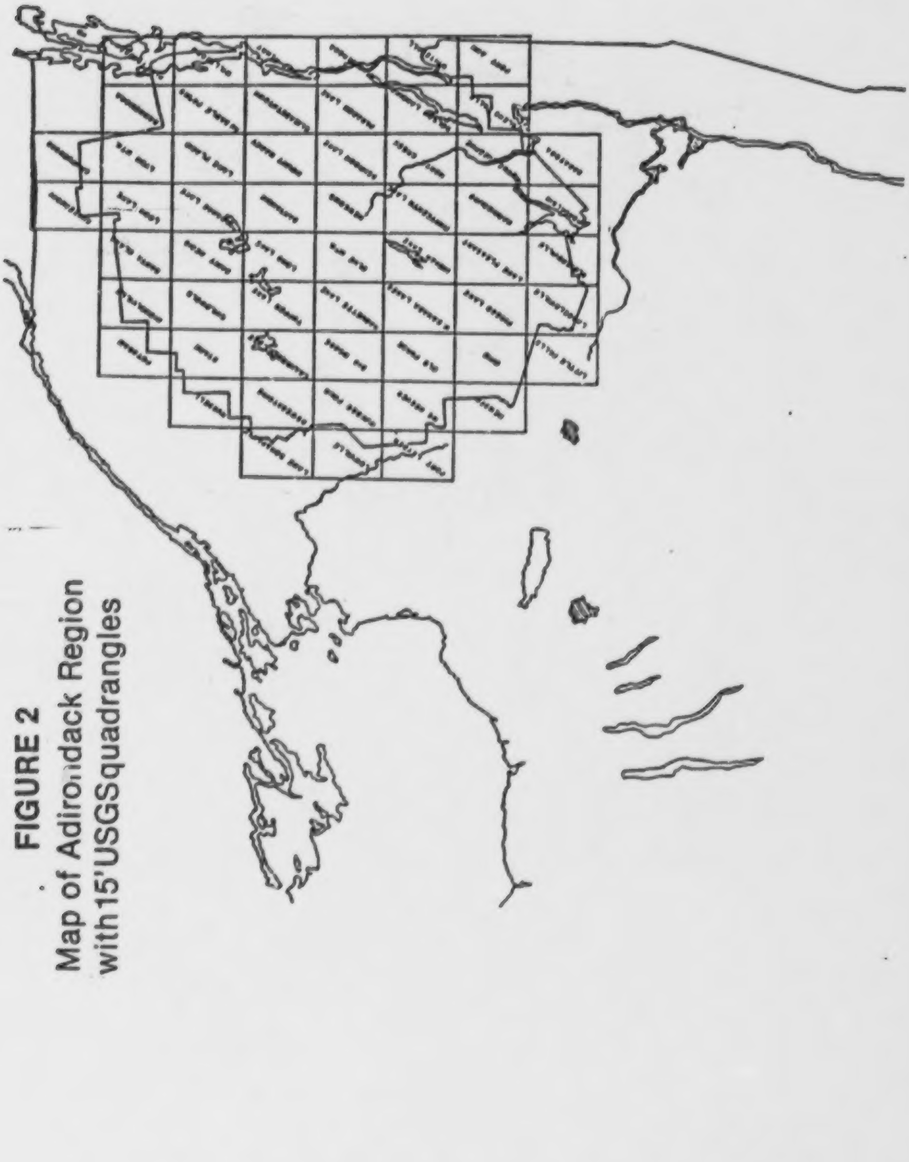
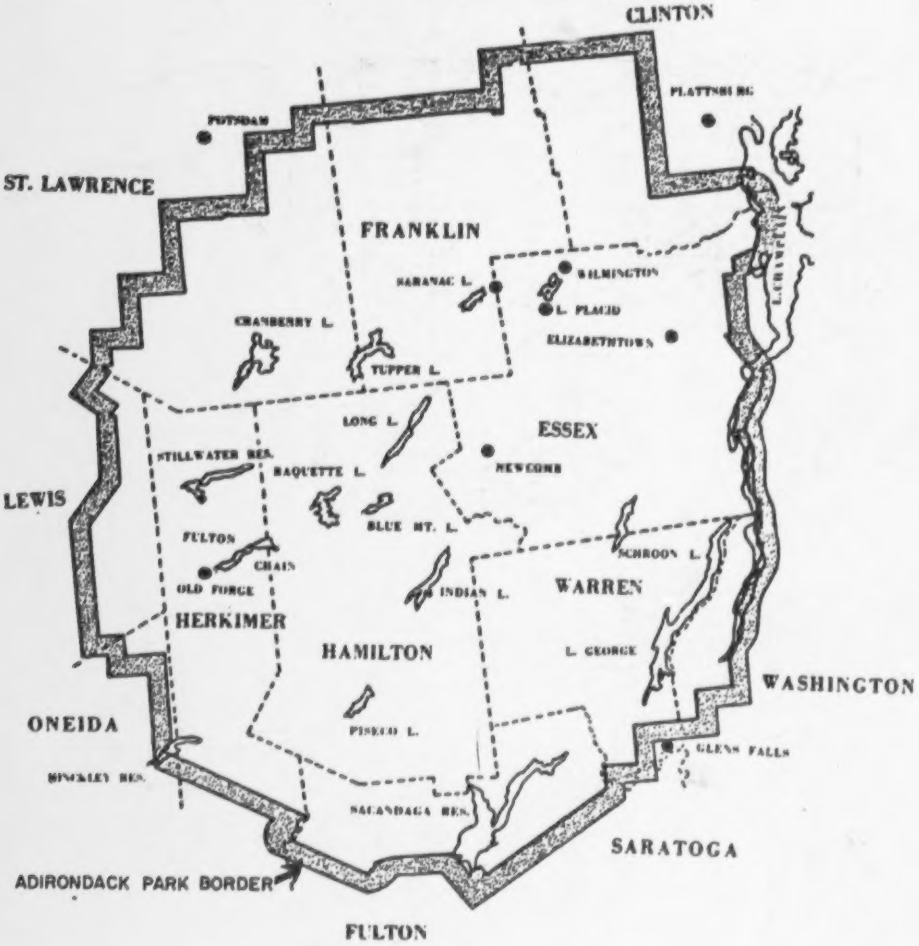


FIGURE 2
Map of Adirondack Region
with 15' USGS quadrangles

FIGURE 3
ADIRONDACK MOUNTAIN REGION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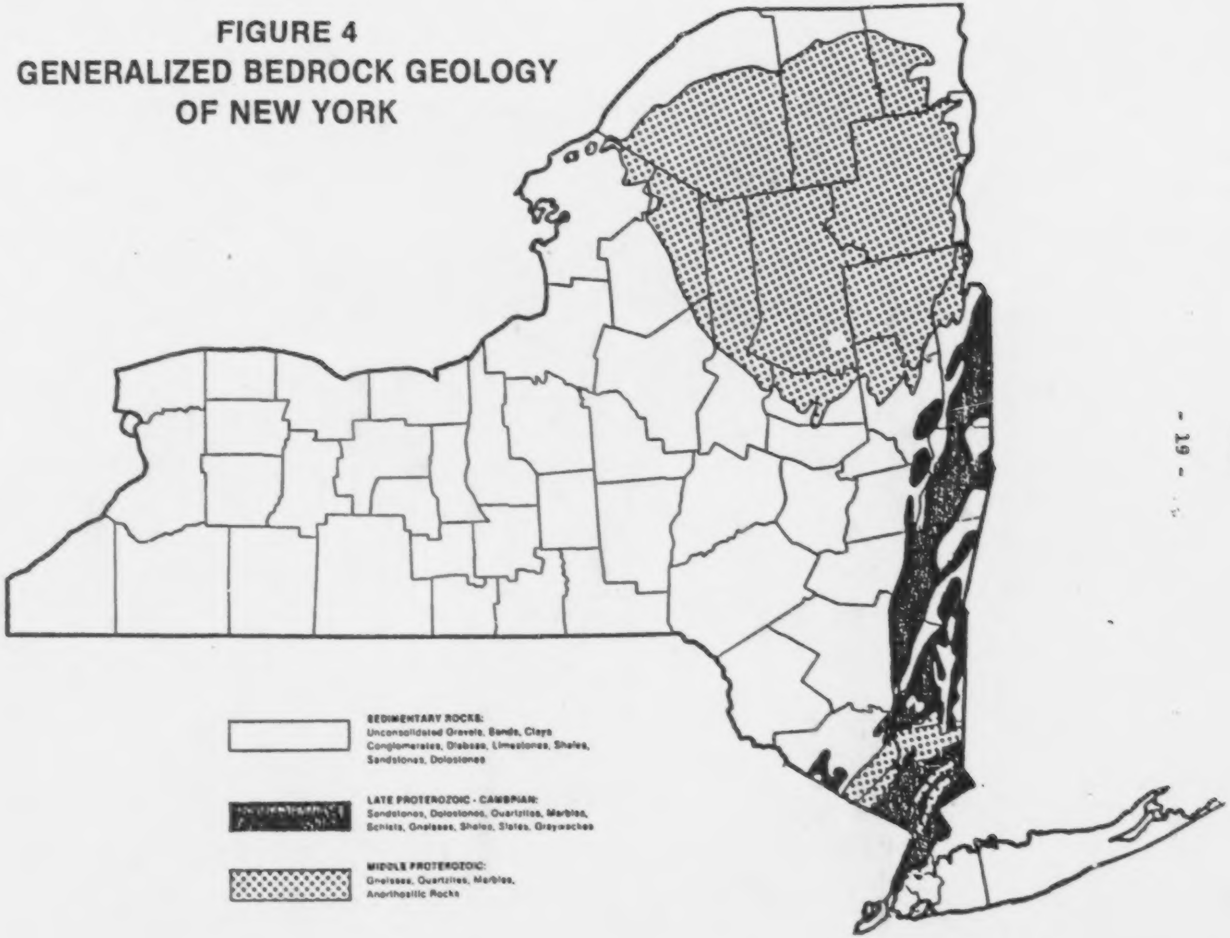
POTSDAM
ST. LAWRENCE
FRANKLIN
SARANAC L.
WILMINGTON
L. PLACID
ELIZABETHTOWN
L. CHAMPLAIN
CRANBERRY L.
TUPPER L.
LONG L.
ESSEX
NEWCOMB
STILLWATER RES.
RAQUETTE L.
LEWIS
BLUE MT. L.
FULTON
CHAIN
SCHROON L.
OLD FORGE
INDIAN L.
WARREN
HERKIMER
HAMILTON
L. GEORGE
WASHINGTON
ONEIDA
PISECO L.
GLENS FALLS
HINCKLEY RES.
SACANDAGA RES.
SARATOGA
ADIRONDACK PARK BORDER
FULTON

FIGURE 4
GENERALIZED BEDROCK GEOLOGY
OF NEW YORK


SEDIMENTARY ROCKS:
Unconsolidated Gravels, Sands, Clays
Conglomerates, Diabase, Limestones, Shales,
Sandstones, Dolostones
LATE PROTEROZOIC - CAMBRIAN:
Sandstones, Dolostones, Quartzites, Marbles,
Schists, Gneisses, Shales, Slates, Graywackes
MIDDLE PROTEROZOIC:
Gneisses, Quartzites, Marbles,
Anorthositic Rocks

DISTRIBUTION OF SUMMER pH VALUES
FOR WATERS SAMPLED SINCE 1974
FIGURE 5

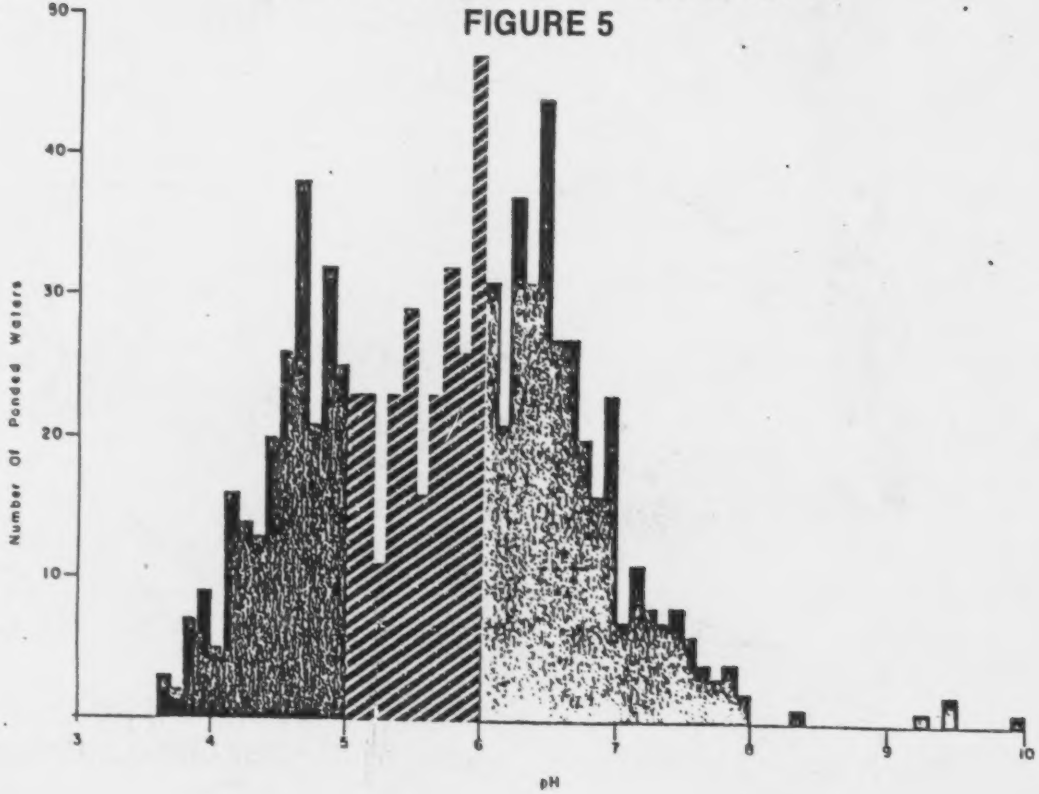
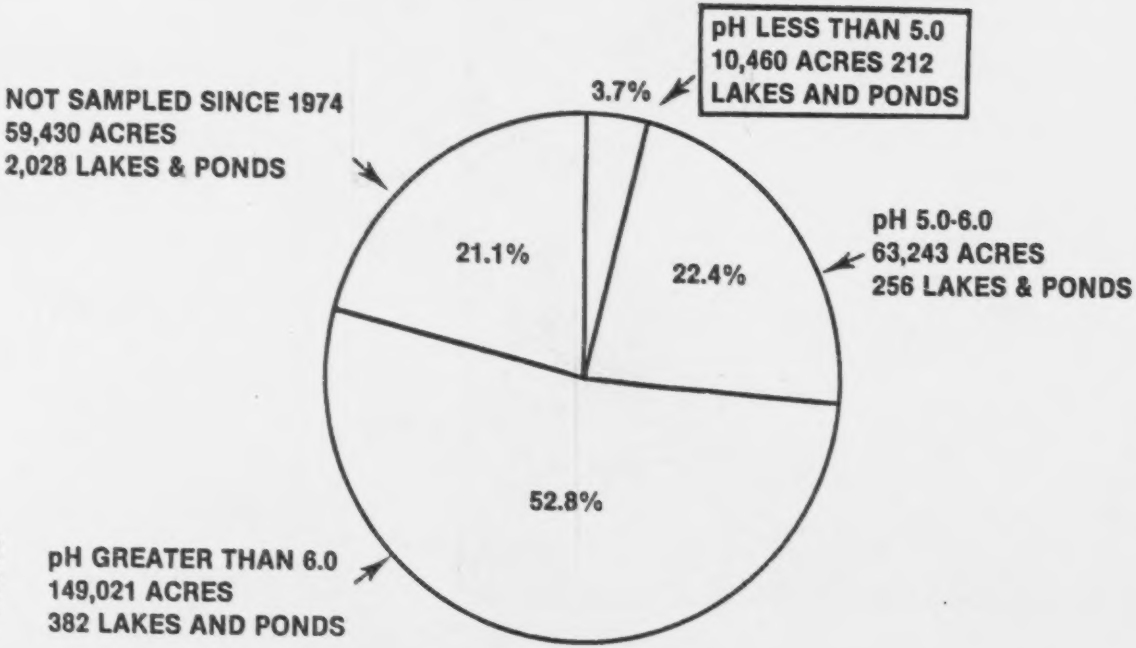


FIGURE 6 ACIDITY STATUS OF ADIRONDACK PONDED WATERS



TOTAL ACREAGE: 282,154

TOTAL # LAKES & PONDS: 2,877

OCCURRENCE BY SIZE
OF WATERS HAVING SUMMER pH OF LESS THAN 5.0

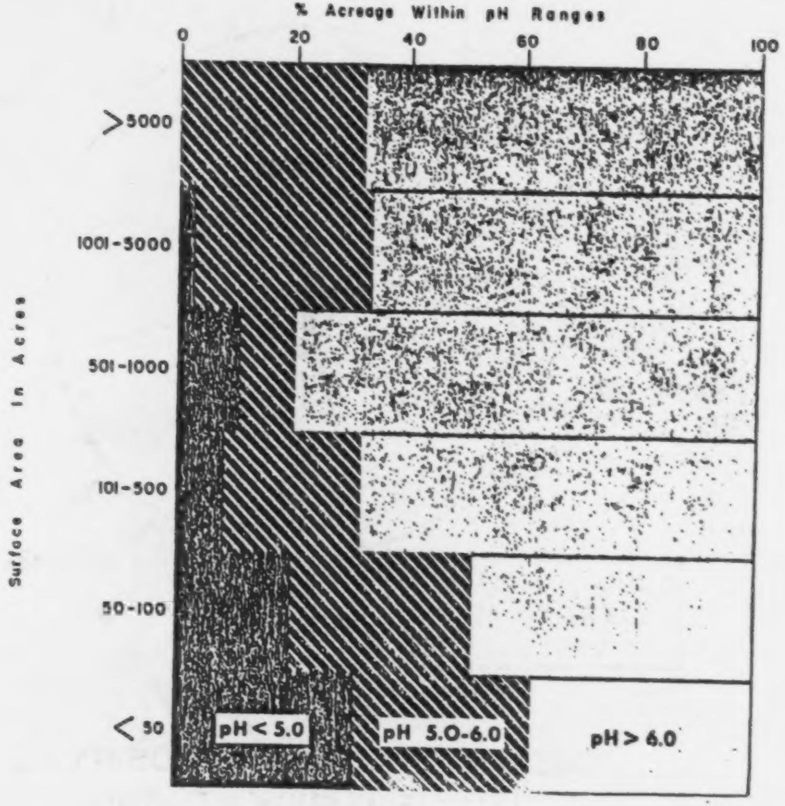


FIGURE 7

OCCURRENCE BY ELEVATION OF *ADIRONDACK* WATERS IN VARIOUS pH CATEGORIES

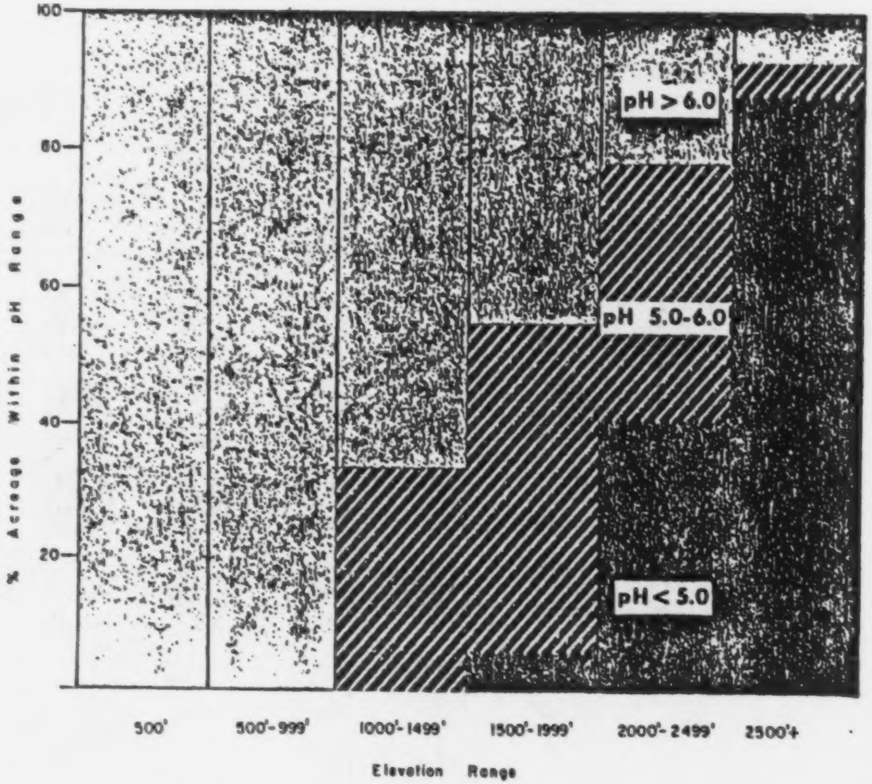
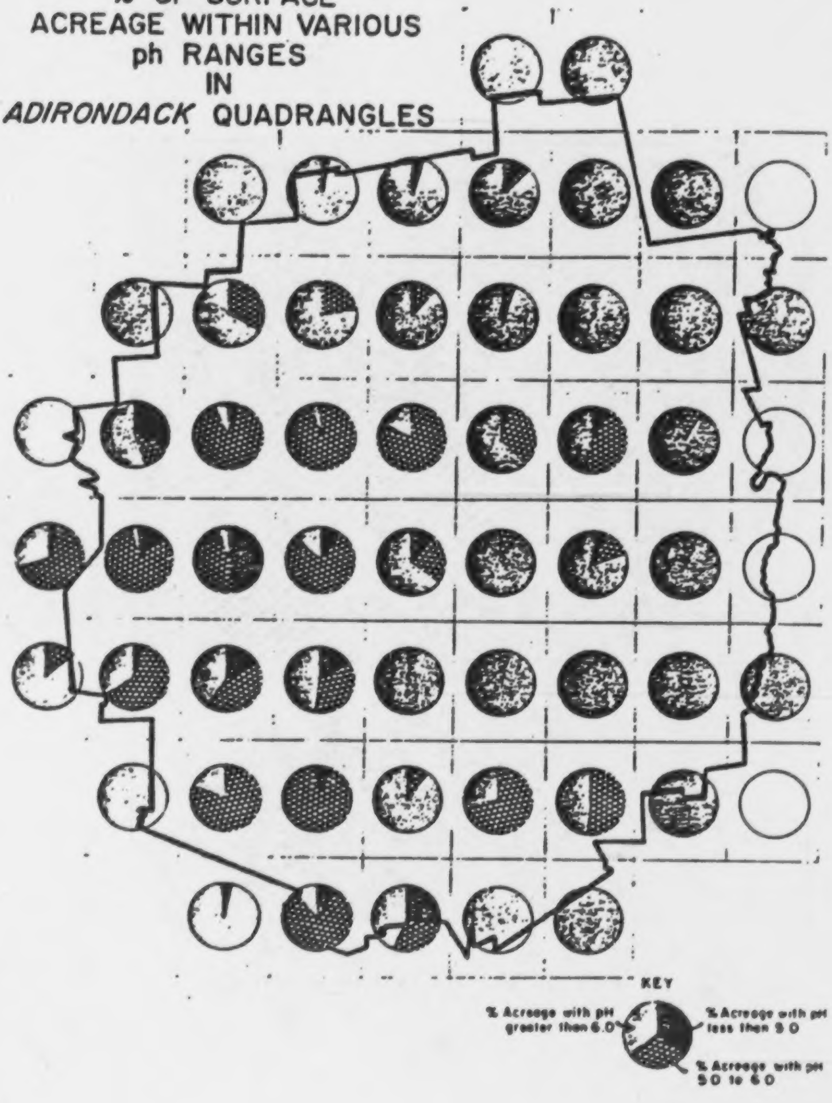
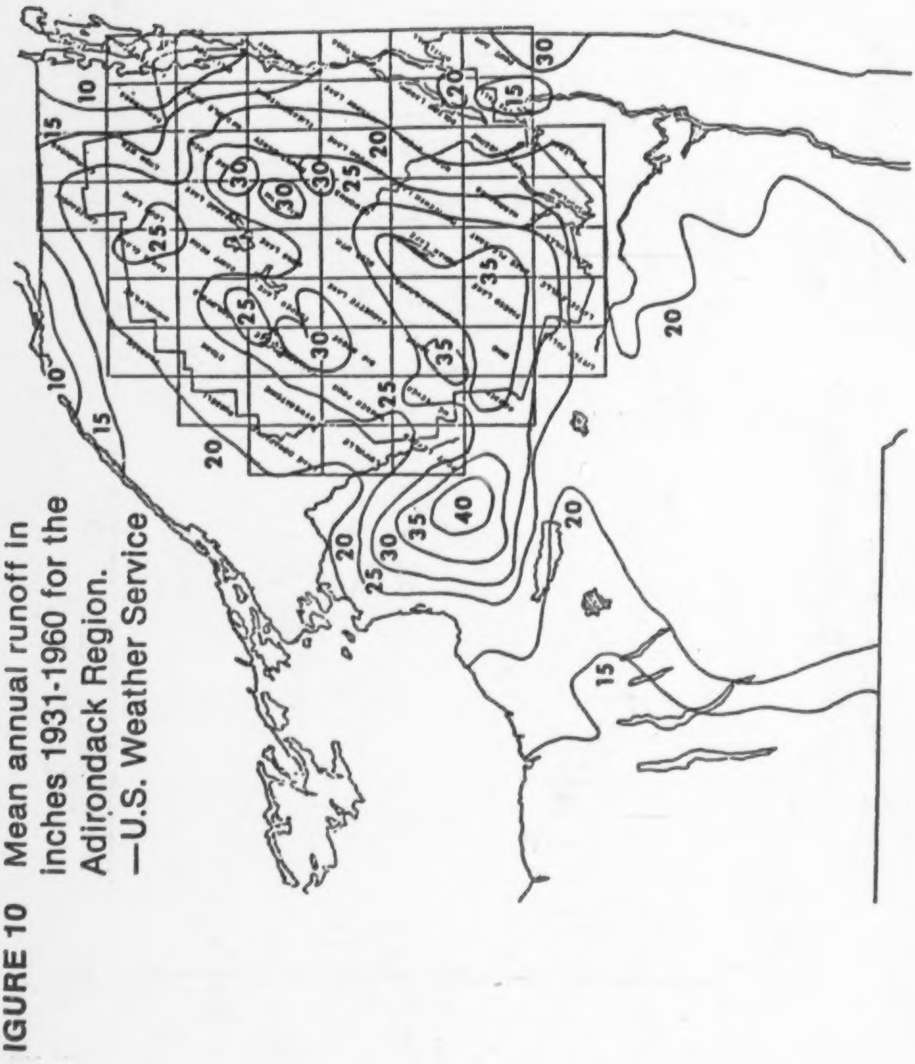


FIGURE 8

FIGURE 9
% OF SURFACE
ACREAGE WITHIN VARIOUS
ph RANGES
IN
ADIRONDACK QUADRANGLES


KEY
% Acreage with pH greater than 6.0
% Acreage with pH less than 5.0
% Acreage with pH 5.0 to 6.0


10
15
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15

IGURE 10 Mean annual runoff in inches 1931-1960 for the Adirondack Region.
—U.S. Weather Service

FIGURE 11 RELATIONSHIP BETWEEN pH–ALKALINITY FOR 100 ADIRONDACK WATERS

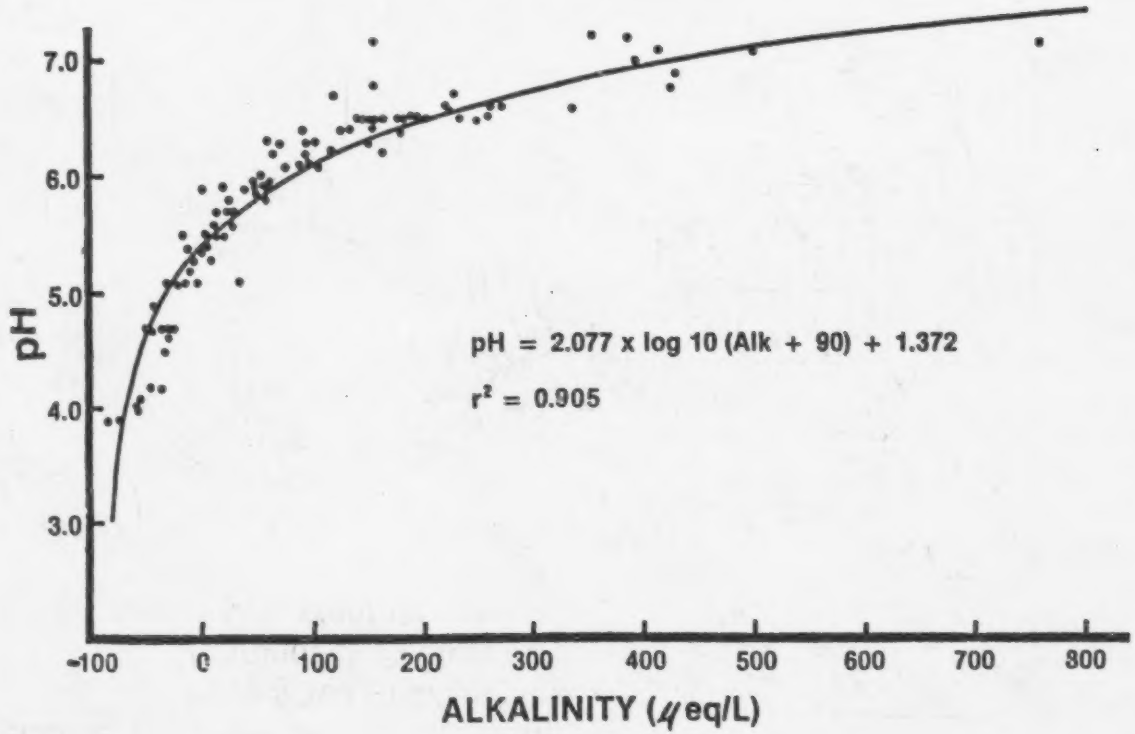
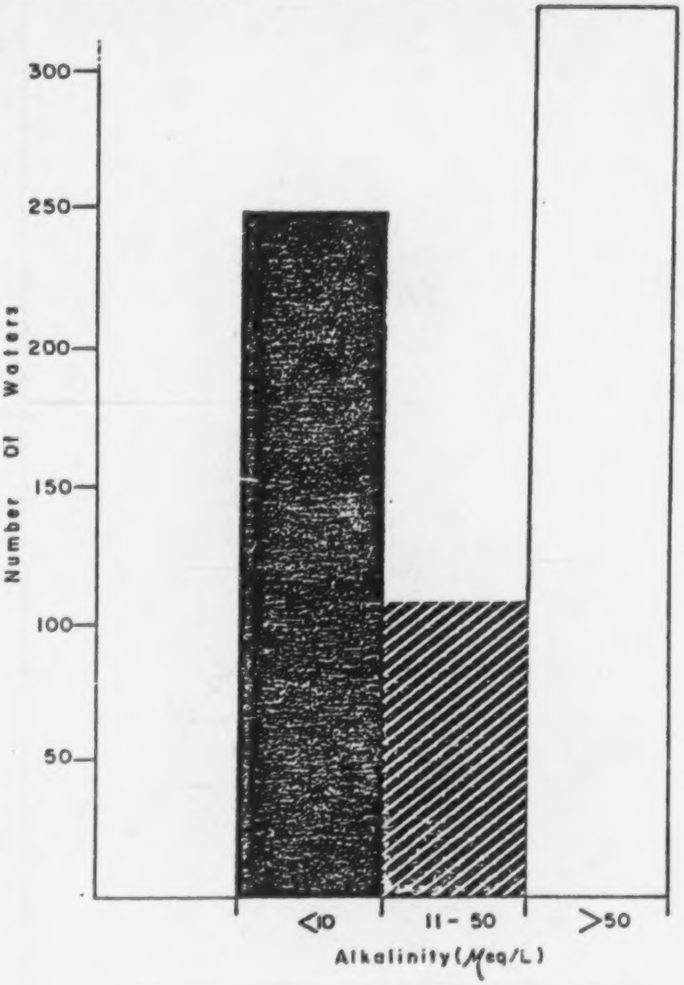


FIGURE 12
DISTRIBUTION
OF SUMMER ALKALINITY MEASUREMENTS
FOR WATERS SAMPLED SINCE 1974



AND ALKALINITY FOR ADIRONDACK WATERS

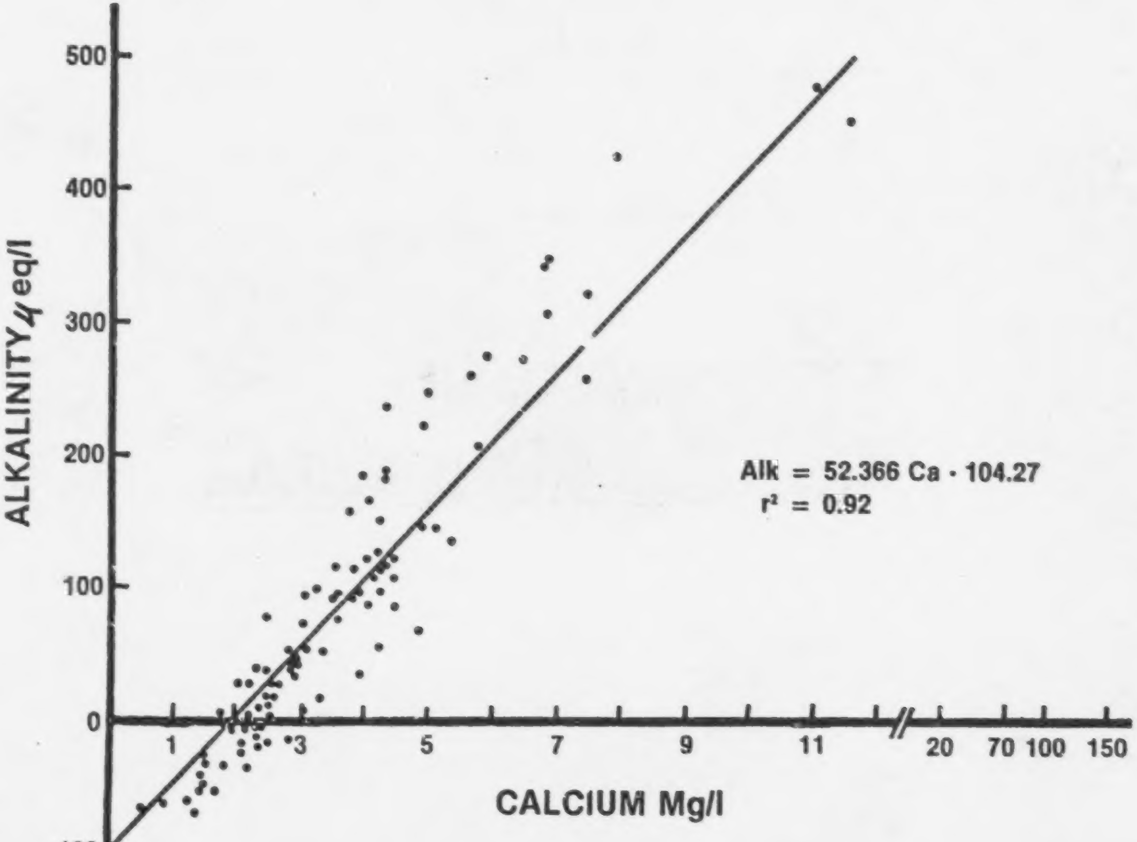


FIGURE 15 RELATIONSHIP BETWEEN pH AND CONDUCTIVITY FOR 100 ADIRONDACK WATERS

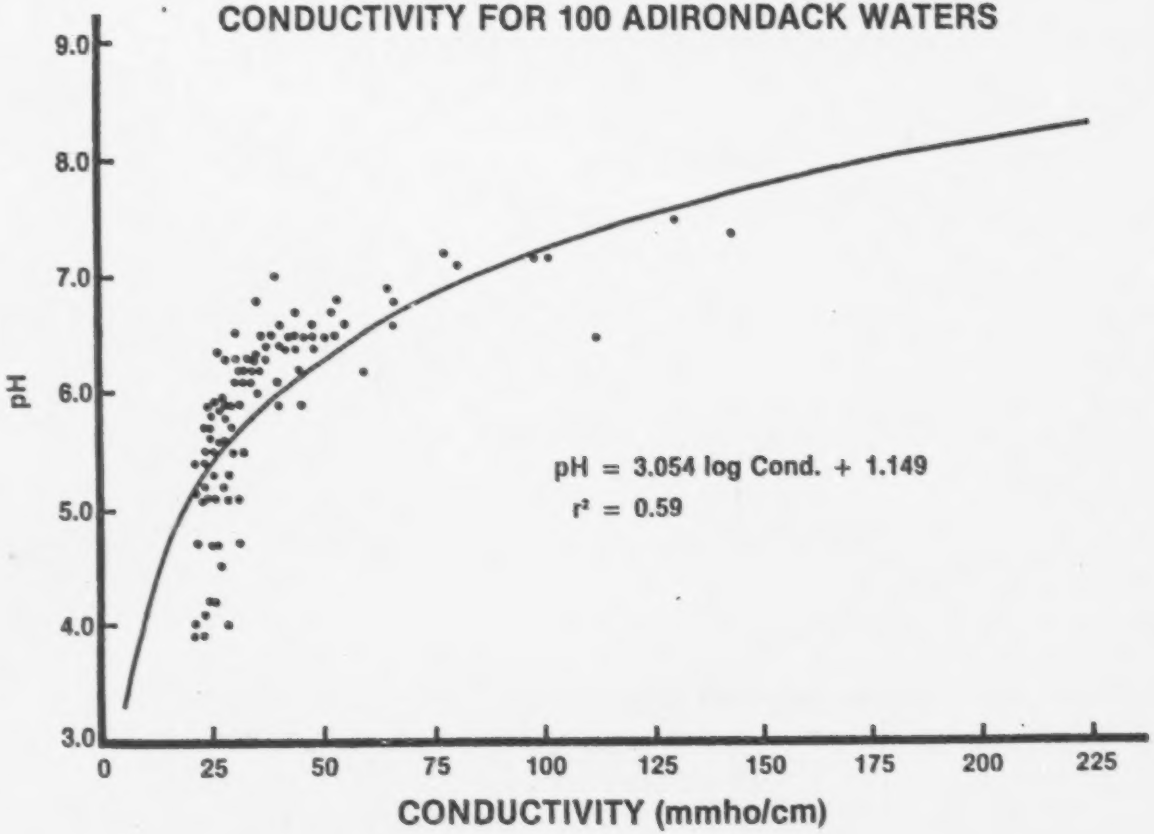


FIGURE 16
COMPARISON OF
METER pH AND COLORIMETRIC (HELLIGE) pH READINGS
FOR 100 ADIRONDACK LAKE SAMPLES

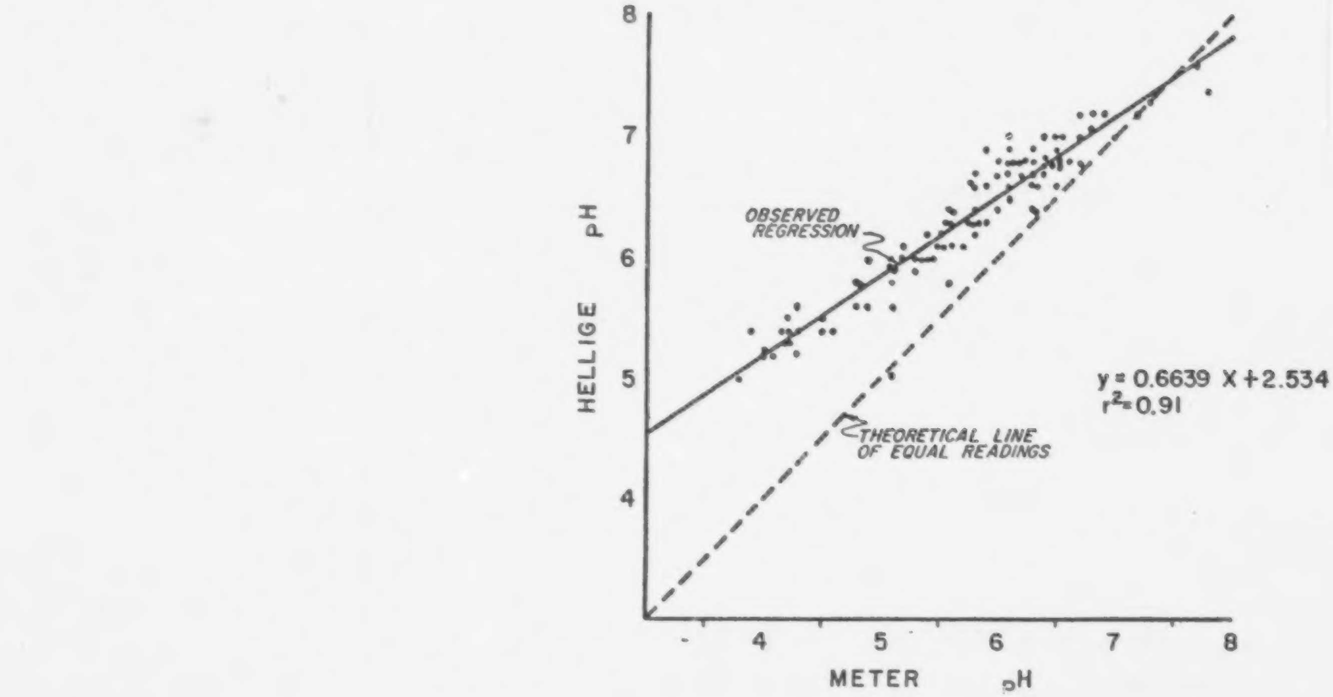
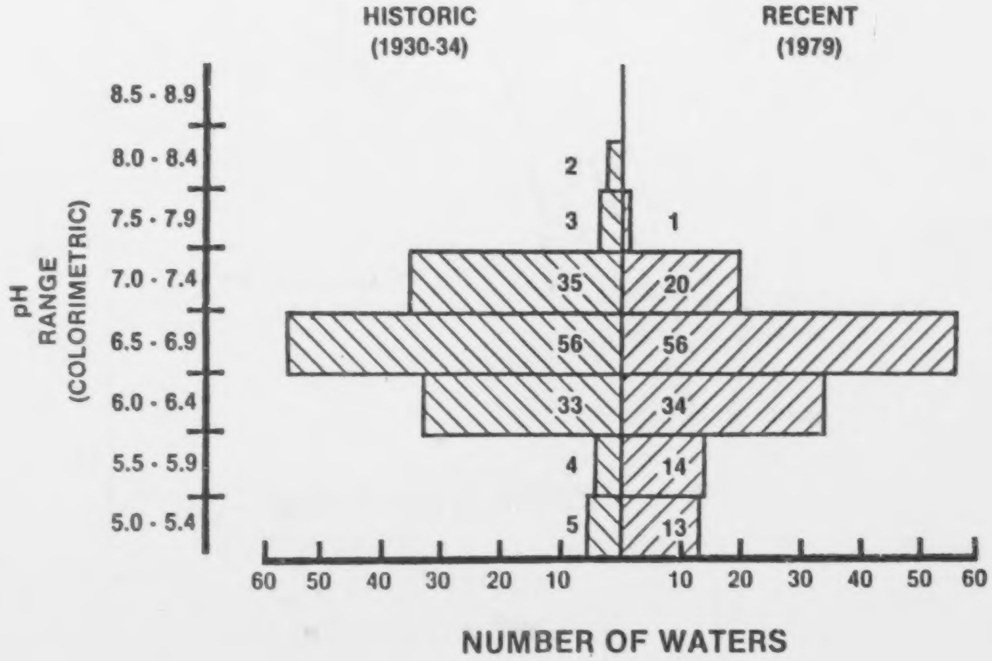


FIGURE 17 CHANGE IN COLORIMETRIC DETERMINED pH DISTRIBUTION OF 138 ADIRONDACK LAKES



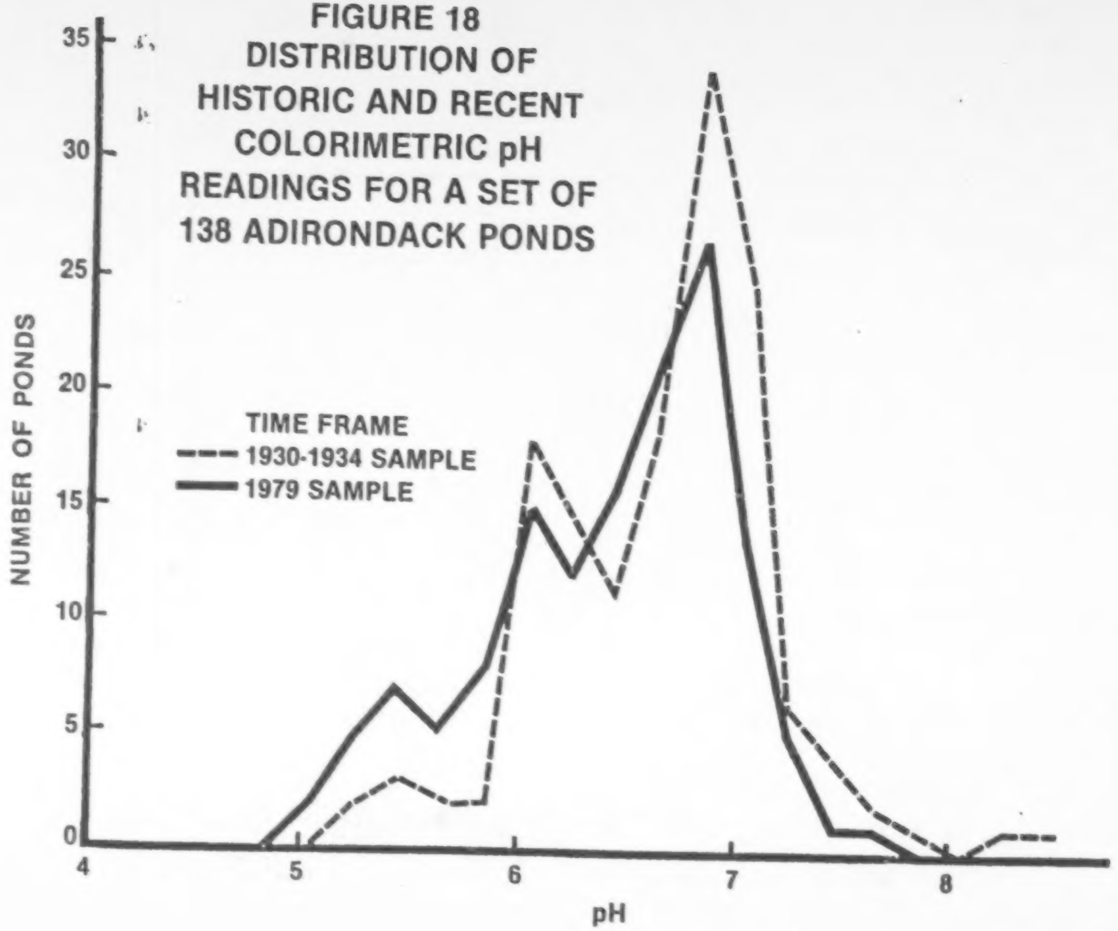


FIGURE 18
DISTRIBUTION OF
HISTORIC AND RECENT
COLORIMETRIC pH
READINGS FOR A SET OF
138 ADIRONDACK PONDS

FIGURE 19 CUMULATIVE COMPARISON OF HISTORIC AND RECENT pH VALUES FOR A SET OF 138 ADIRONDACK LAKES

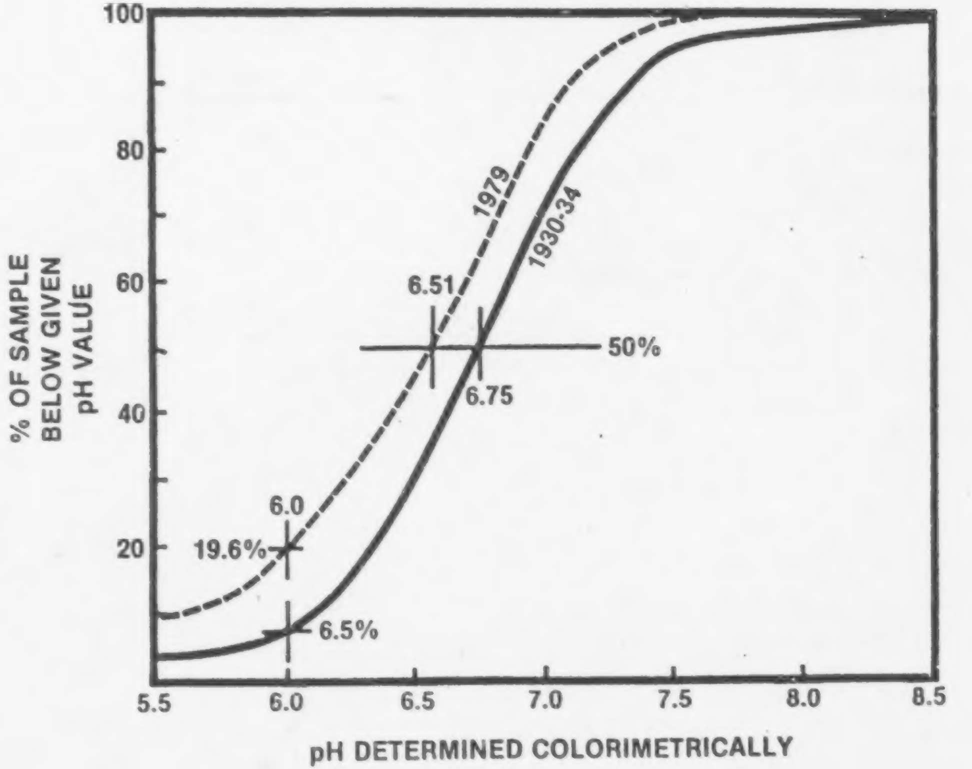
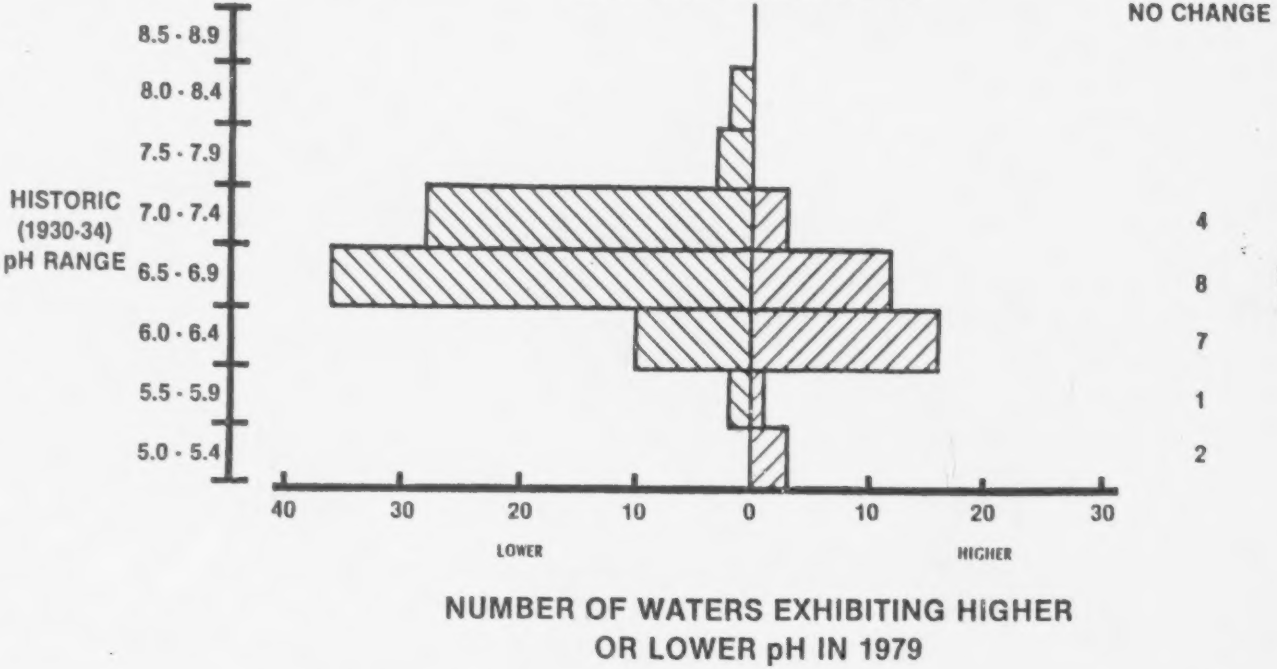


FIGURE 20 COMPARISON OF HISTORIC AND RECENT pH VALUES (COLORIMETRIC) FOR A SET OF 138 ADIRONDACK LAKES



LITERATURE REFERENCES

Beamish, R.J. 1976. Acidification of Lakes in Canada by Acid Precipitation and the Resulting Effects on Fishes. In Proceedings of the International Symposium on Acid Precipitation and the Forest Ecosystem, USDA Forest Service General Tech. Report NE-23, NE Forest Experiment Station, Upper Darby PA. pp 449-498.

Pfeiffer, M. H. 1979. A Comprehensive Plan for Fish Resource Management Within the Adirondack Zone. Department Report, Bureau of Fisheries, N.Y. State Dept. Env. Cons. 207 pp.

Schofield, C. L. 1977. Acidification of Adirondack Lakes by Atmospheric Precipitation: Extent and Magnitude of the Problem. Final report for Project F-28-R, N.Y. State, U.S.F.W.S. - (Unpublished Report)

______________. 1978. Guidelines for Survey and Monitoring of Acid Sensitive Waters in New York State. N.Y. State College of Agriculture and Life Sciences, Cornell Univ., Ithaca, New York for N.Y.S. Dept. of Env. Cons. (Unpublished Report) 15 pp.

Appendix I

Adirondack Lake and Pond Survey
Key Chemistry Information

July 1980

Appendix to NYSDEC Report "Acidity Status of Lakes in the Adirondack Region of New York in Relation to Fish Resources" by Martin H. Pfeiffer and Patrick J. Festa - July 1980

Explanation of Codes

W'SHED P#: The watershed number refers to the major basin in which the lake or pond lies and follows the watershed boundaries described in the 1930-1934 Biological Surveys. The P# is the identification number assigned to individual ponded waters within each watershed. Example: 5-587A Adirondack Lake - 5 is the code for the Upper Hudson Watershed, 587A is the pond number assigned to Adirondack Lake. Following are the watershed codes used in Appendix I.

Code	Watershed	Code	Watershed
01	Oswego	05	Upper Hudson
02	Lake Champlain	06	Raquette
03	St. Lawrence	07	Mohawk Hudson
04	Oswegatchie/Black	08	Ontario
		09	Delaware/Susquehanna

7.5' QUAD: Refers to the 7 1/2 minute Latitude x Longitude U. S. Geological Survey Quadrangle in which the outlet of the lake lies. Many areas of the Adirondacks have only been mapped on 15 minute quadrangles; in these cases, the last digit refers to 7 1/2' quadrant on the 15 minute map in which the lake or pond outlet lies. Example: F233 refers to the South-West quadrant of the Blue Mountain 15' USGS Quadrangle. The code and relative location of the 15' quadrangles are displayed on the accompanying diagram.

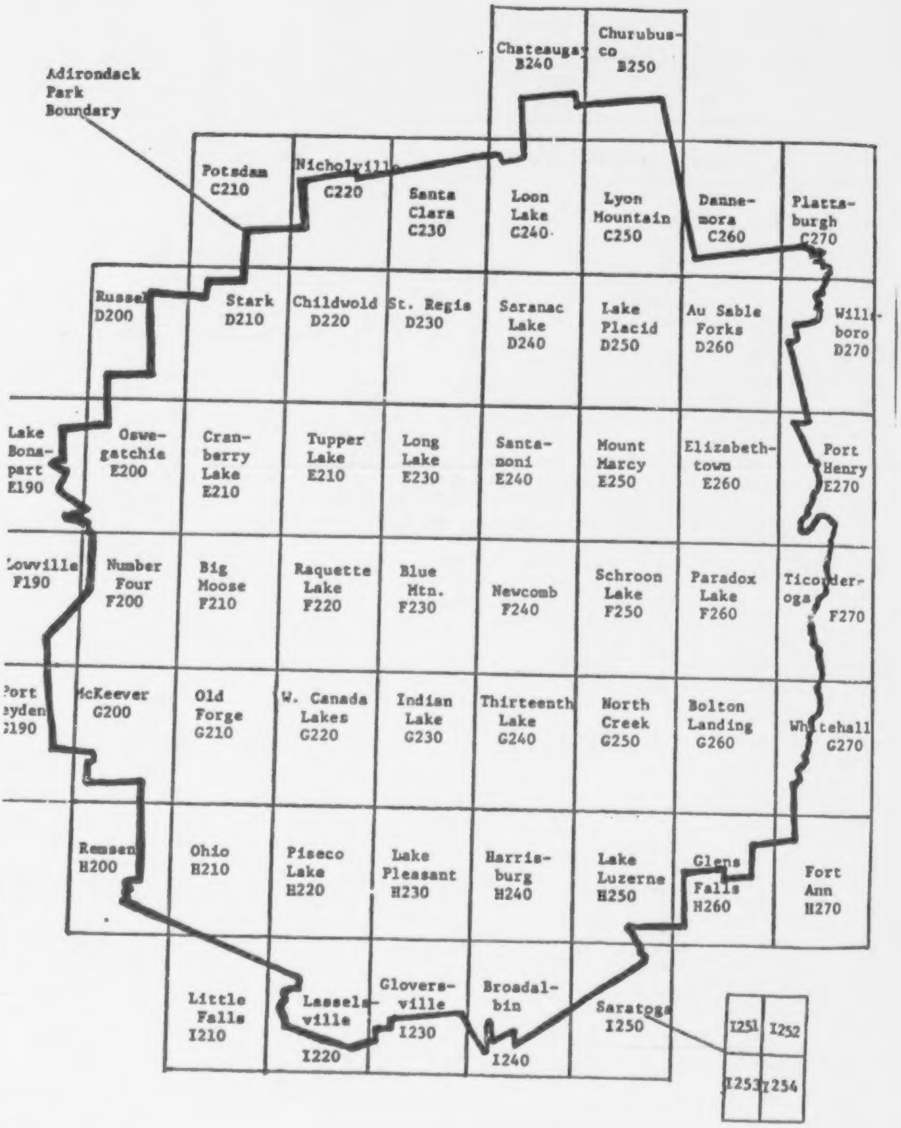
SURF AREA: Area of the lake surface to nearest acre. Taken from "Characteristics of New York Lakes, Part I Gazetteer of Lakes, Ponds and Reservoirs, Bulletin 68, 1970, by U. S. Geological Survey and NYSDEC, or from U.S.G.S. Topographical Maps.

SURF ELEV: Elevation, in feet above mean sea level, of the lake surface. Elevation was taken from "Part I Gazetteer of Lakes, Ponds and Reservoirs, U.S.G.S. Topographical Maps or NYSDEC survey maps.

CNTY: Refers to the county in which the lake or pond outlet lies.

County Codes

Code	County	Code	County
10	Clinton	29	Montgomery
16	Essex	33	Oneida
17	Franklin	38	Oswego
18	Fulton	45	St. Lawrence
21	Hamilton	46	Saratoga
22	Herkimer	47	Schenectady
23	Jefferson	57	Warren
25	Lewis	58	Washington


Adirondack Park Boundary
Chateaugay B240
Churubusco B250
Potsdam C210
Nicholville C220
Santa Clara C230
Loon Lake C240
Lyon Mountain C250
Dannemora C260
Plattsburgh C270
Russel D200
Stark D210
Childwold D220
St. Regis D230
Saranac Lake D240
Lake Placid D250
Au Sable Forks D260
Willsboro D270
Lake Bonapart E190
Oswegatchie E200
Cranberry Lake E210
Tupper Lake E210
Long Lake E230
Santanoni E240
Mount Marcy E250
Elizabethtown E260
Port Henry E270
owville F190
Number Four F200
Big Moose F210
Raquette Lake F220
Blue Mtn. F230
Newcomb F240
Schroon Lake F250
Paradox Lake F260
Ticonderoga F270
Port eyden 190
McKeever G200
Old Forge G210
W. Canada Lakes G220
Indian Lake G230
Thirteenth Lake G240
North Creek G250
Bolton Landing G260
Whitehall G270
Remsen H200
Ohio H210
Piseco Lake H220
Lake Pleasant H230
Harrisburg H240
Lake Luzerne H250
Glens Falls H260
Fort Ann H270
Little Falls I210
Lasselsville I220
Gloversville I230
Broadalbin I240
Saratoga I250
I251
I252
I253
I254

ADK ZONE: Refers to the NYSDEC Fisheries classification for the subject water

Code	
1	Brook Trout Ponds
2	Two-Story Lakes and Ponds - contains both coldwater and warmwater sport fish
3	Cold Water Ponds - contains trout and/or salmon other than brook trout and not managed primarily for brook trout
4	Warm Water Lakes and Ponds - contains warmwater sport fish species; i.e., bass, walleye, pike.
5	Acidified Lakes and Ponds - high acidity prohibits maintenance of viable sport fish population
6	Fisheries Classification Undetermined
7	Limed - Maintenance of sport fish population dependent upon treatment with lime.

DATE PH: The date on which the water sample was collected

SURF PH: pH of sample collected at or within 1 meter of lake surface. All 1979 dated samples were collected at 1 meter depth.

PH MTH: The analysis method employed for determining sample pH. Eq.M = Equilibrium Meter. Determination made under air CO_2 equilibrium conditions with laboratory grade electronic pH meter by procedures described in Appendix II. METER = determination made with electronic pH meter, not necessarily under air CO_2 equilibrium conditions. Readings on 1975 dated samples were taken after the sample was vigorously shaken. UNKN = Method of pH determination unknown. Most of these readings were obtained in the field with portable, battery operated pH meters.

ALKAL UEQ/L: Total alkalinity reported as micro-equivalents per liter (ueq/l). 1979 and 1975 dated samples were analyzed via procedures in Appendix II.

SURF COND: Surface conductivity reported in μmhos/cm. Obtained via electronic conductivity meter.

CA MG/L: Total calcium concentration reported in mg/l. Analysis via Atomic Absorption Spectrophotometric Analysis.

DATA SOURCE:
1 - Samples collected and analyzed by NYSDEC staff
2 - Samples collected and analyzed by Dr. Carl Schofield, Cornell University, under research contract administered by NYSDEC and partially funded by U. S. Fish and Wildlife Service, Dingell-Johnson Federal Aid to Fisheries Funds
3 - Data contributed by Don Charles of Indiana University, collected as part of M.S. thesis work.

[illegible]

[illegible]

HUDSON INSTITUTE
POLICY RESEARCH IN THE PUBLIC INTEREST
QUAKER RIDGE ROAD CROTON ON HUDSON, N.Y. 10520 • TELEX 137343 • 914 762-0700

December 20, 1983

[illegible]

AN OPEN LETTER TO GOVERNOR CUOMO REGARDING ACID RAIN LEGISLATION

The Honorable Mario Cuomo
Governor of the State of New York
2 World Trade Center
57th Floor
New York, N.Y. 10047

Dear Governor Cuomo:

The New York Times reported on December 6, 1983 that you and several other governors of the northeastern states strongly favor national acid-rain legislation that would reduce by some 10-12 million tons the amount of sulfur dioxide being emitted into the atmosphere each year, and thereby hope also to reduce rainfall acidity and its effects in the U.S., especially in the eastern states. I believe that every citizen in the country shares your desire to reduce those noxious emissions. One of the problems, that you and the other governors well understand, is that the proposed legislation would impose a costly burden on the country and that it might be difficult or impossible to avoid placing a relatively heavy part of that burden on a few of the midwestern states which burn a lot of high-sulfur coal, while other areas of the country might hardly be affected at all.

My purpose in writing this letter is to list a few crucial facts in the acid-rain debate which might not have been brought to your attention--in part, because some of them have only recently been uncovered. This information might even persuade you and the other governors to reconsider and possibly modify your position on the proposed legislation. Indeed, it seems to me to be possible that your present position might soon become an embarrassment which should and can be avoided.

You might wish to know that the information I am presenting below derives from a study which my colleagues and I at the Hudson Institute completed on November 1, 1983. This information suggests significantly different conclusions from those which appeared to be reasonable in numerous studies completed prior to 1983. Of course I am enclosing for your examination a copy of our study ("A Perspective on Current Acid Rain Issues").

WASHINGTON OFFICE [illegible] BOULEVARD [illegible]
ASIA PACIFIC OFFICE KOWA BLDG NO 9, 1-8-10 AKASAKA, [illegible] JAPAN
HUDSON OF CANADA, 460 SHERBROOKE STREET WEST SUITE #907, MONTREAL, QUEBEC H3A 1E7 CANADA

Point #1: Although the costs of the proposed legislation are necessarily uncertain they have been variously estimated to range between \$3 billion and \$12 billion per year in constant 1982 dollars. Once the required changes are made those costs might then continue for roughly 25 years. Our study concluded that a reasonable estimate of the discounted real cost to the nation would be about \$100 billion (again in 1982 dollars). This estimate is based upon an \$8 billion annual cost and a 6 percent constant-dollar discount rate. If the nation is to commit \$100 billion to a partial reduction of industrial sulfur dioxide emissions then we should be reasonably confident that the benefits of that expenditure would be worthwhile. That brings up the following points.

Point #2: The most important argument which has been used to justify the proposed legislation is that the acid in precipitation enters into our aquatic systems and threatens the fish and other creatures which inhabit them. It has been shown that over 200 lakes in the Adirondack Mountains--and the streams that feed them--are now devoid of fish--at least of trout and other game fish. As there is little doubt that the stress to fish populations derives from the effects of acidified water it has become easy for people to accept the simple image that (a) acidified precipitation falls onto the watershed, (b) runs into the streams and lakes, and (c) kills the fish in any waters which lack enough natural alkaline buffers to neutralize the acid. Morerver, claims are frequently heard that the continuing acid deposition will, over time, cause increasing acidity in more and more lakes, and could lead to widespread disastrous results in the U.S., Canada and Europe. If that is a real threat then spending \$100 billion to stop it clearly would not be excessive. However it now appears that the above image and its obvious conclusion was arrived at too hastily. The underlying reality is more complex and, fortunately, far less threatening. I will try to describe its bare essentials to you very briefly.

First, whether acid or not, rain does not simply run unaffected into our aquatic systems. Except for a small portion which falls directly into lakes, precipitation which ends up in these lakes passes through a series of filters in the watershed, each of which affects its acidity. The first filter is the forest canopy. The second is the top layer of the forest floor which includes the shrubs, grasses, ferns and litter. Although in some forests most of the acid in rainfall is removed by these two filters the third layer, the decomposed vegetation or humus, is usually the critical one. In northeastern forests the humus is usually a few inches thick and contains a large quantity of natural acids. In the coniferous forests, prevalent in many regions throughout the temperate zone, the acidity of the humus--called mor humus--is especially high. Indeed it has been calculated that 6 inches of mor humus contains about 500 to 1000 times as much acid as falls upon eastern watersheds from acid precipitation over the course of a year. Moreover, regardless of its initial acidity or alkalinity, the water passing through mor humus emerges with a much greater acidity than that originally present in acid rain! That is, forests of the temperate zones--especially coniferous forests--are natural acid-creators, produce far more acid than the mere 1/80 of an ounce per square foot that falls upon our eastern watersheds annually, and will acidify any water seeping through the soil.

This relatively great acidification of both rainfall and melting snow percolating through mor humus layers would long ago have killed off the desirable fish in all nearby lakes and streams were it not for the fact that still other filters exist through which the runoff usually must percolate before it enters the streams. These deeper filters are the porous mineral layers which are often several feet thick and which, over nearly all land areas, are alkaline. Except in a few sensitive areas these minerals contain a huge amount of alkaline substances such as limestone which neutralize the acidity of any waters seeping through them on the way to streams and lakes and thereby prevent these waters from becoming inhospitable to fish.

Unfortunately, in a few sensitive areas the deeper soil layers do not contain limestone or any other alkaline minerals which can neutralize the acidic water emerging from the humus above them. Within those areas we must expect existing aquatic systems to be acidic unless fires burned down the forest and destroyed the acid-producing humus in the relatively recent past--and replaced it with a layer of alkaline ashes. When that happens naturally acidified lakes may become neutralized and more hospitable to fish for perhaps a few decades--until the forest regrows and the humus is regenerated.

However, during the last few decades, thanks in part to the efficient U.S. Forest Service, ortheastern forests have expanded remarkably in volume. That growth can only have increased the amount of humus and natural acidity, but in only a few areas of the U.S. have the waters been affected much. Even in the Adirondacks, which evidently is the most sensitive region in North America, the non-alkaline mineral layers exist in irregular and scatered "patches." Consequently, most of the Adirondacks' aquatic systems are not acidified--nor should we expect them to become so.

Point #3: I have read many reports, Governor, which have considered the possibility that acid rain is the direct cause of the few acidified aquatic systems. Whether it is through a lack of information or through prior commitment to a preconceived goal (i.e., stop acid rain) I have found that those studies which contend that acid rain is the most likely culprit are based only on circumstartial evidence which does not contain (or avoids) the information which is presented above. Indeed my colleagues and I might also have become "guilty" of arriving at a similar conclusion had our research not come across a recent publication in Science by two soil scientists (Drs. Edward Krug and Charles Frink, August 5, 1983) which portrayed the essential elements of the filtering process outlined above. As of now only a few of the concerned scientists have had sufficient time to digest that study and its implications, but that will no longer be true a year from now.

Point #4: In this letter I have not addressed other claims about the damage attributed to acid rain. Our study does examine each of the major claims of possible damage to forests, human health, agricultural crops, and materials. While it is possible that some of these or other claims may yet be proven, my colleagues and I were astonished at the extent to which the evidence was weak, circumstantial, or occasionally simply wrong (that is disproved since it was asserted).

Accordingly our study, which still favors a continuation and strengthening of the Clean Air Act, concluded that from a scientific point of view the proposed acid rain legislation could not be justified. There are many far better ways, in our judgment, to spend $100 billion.

I can only suggest, Governor, that you might want to ask your technical staff to review the most recent scientific evidence before you continue on the course you have recently preferred with respect to acid-rain. If our study and this letter is of help to you in this regard then it may also be of help to our legislators in Washington.

Most sincerely yours,

William M. Brown, Ph.D.
Director
Energy and Technology Studies

WMB:mp
Enc.

APPENDIX B

Materials Submitted for the Record at the Request of Senator George Mitchell

---

1. "A Seaboard of Stunted Trees", The New York Times, March 2, 1984.

2. "Assessing the Effects of Acid Rain on Forests of the Eastern U.S.", Testimony before the United States Senate Committee on Environment and Public Works by Arthur H. Johnson, Associate Professor, University of Pennsylvania, Philadelphia, Pennsylvania. February 7, 1984.

3. "Testimony on Regional Changes in the Growth and Behavior of Forests in Central Europe and the Eastern North America", by Dr. Ellis B. Cowling, Associate Dean for Research, School of Forest Resources, Assistant Director, North Carolina Agricultural Research Service, North Carolina State University, Raleigh, North Carolina. (Testimony before the Senate Committee on Environment and Public Works.) February 7, 1984.

    a. Memo on, "Observations in German Forests during the late Summer of 1983", from Ellis B. Cowling to his colleagues in Forestry Research. October 7, 1983. (Attachment to February 7, 1984 testimony before the Senate Committee on Environment and Public Works) The full document is retained in the Committee files.

    b. "Waldsterben -- A General Decline of Forests in Central Europe: Symptoms, Development, and Possible Causes of a Beginning Breakdown of Forest Ecosystems", by Dr. Peter Schutt, Professor of Forest Botany and Pathology, University of Munich, West Germany. (Attachment to February 7, 1984 testimony by Dr. Ellis B. Cowling before the Senate Committee on Environment and Public Works). The full document is retained in the Full Committee files.

    c. "Observations of Montane Boreal Tree Decline and Dieback in the Southern Appalachian Mountains", a statement prepared for presentation to the United States Senate Committee on Environment and Public Works, by Dr. Robert Ian Bruck, Assistant Professor of Plant Pathology and Forestry, and Ms. Sandra Meier, Graduate Research Assistant, North Carolina State University. (Attachment to February 7, 1984 testimony by Dr. Ellis B. Cowling, before the Senate Committee on Environment and Public Works.) The full document is retained in the Full Committee files.

d. "Discovering the causes, consequences, and implications of acid rain and atmospheric deposition", by Dr. Ellis B. Cowling. Reprinted from the Tappi Journal, The Journal of the Technical Association of the Pulp and Paper Industry, September 1983. (Attachment to February 7, 1984 testimony by Dr. Ellis B. Cowling, before the Senate Committee on Environment and Public Works.) The full document is retained in the Full Committee files.

e. "Four questionable assumptions underlying the Clean Air Act of 1970 and its Amendments of 1977", By Ellis B. Cowling. (Attachment to February 7, 1984 testimony by Dr. Ellis B. Cowling, before the Senate Committee on Environment and Public Works.) The full document is retained in the full Committee files.

4. "Current Status of Research in Acid Rain", By Richard M. Klein and Hubert W. Vogelmann, Botany Department, University of Vermont, Burlington, Vermont.

5. "Statement of Board of Directors Tennessee Valley Authority". Testimony before the Senate Committee on Environment and Public Works, February 9, 1984.

6. "A Rain of Death on the Striper?", special report from Sports Illustrated, by Robert H. Boyle. April 23, 1984.

7. "Letter to the President of the United States", November 17, 1984, from 24 members of Congress.

8. "Region falls victim to own pollution, research indicates", from The Courier-Journal, by Larry Tye. April 8, 1984.

9. "Acid Rain: Its State by State Impacts", by the National Wildlife Federation. Full document retained in full Committee files.

3/2/84

The New York Times

Founded in 1851

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A Seaboard of Stunted Trees

Throughout the Eastern Seaboard of the United States, forests are in serious decline. Several species of tree are growing more feebly than usual, and along the Appalachians' tallest peaks, from Camels Hump in Vermont to Mount Mitchell in North Carolina, the trees are dead or dying. The causes of this massive disaster are not known for sure, but the circumstantial evidence is compelling: only air pollutants, such as acid rain, could damage forests over so wide a range.

Rain is turned acid by the waste gases that spew from coal-burning power plants, particularly those in the Ohio Valley that have tall stacks to export their pollutants. Carried by westerly winds, the sour rain has for decades drenched the lakes and forests of the Eastern Seaboard and Canada.

The insult to the environment is hard to pinpoint because the damage is so diffuse and subtle. Soils can neutralize some acid, organisms can adapt to stress. But year by year, drop by drop, the acid rain has stretched the resilience of natural systems toward breaking point and sapped their resistance to drought and disease.

Lifeless lakes have long been a familiar feature in the Adirondacks, but damage to trees seemed questionable. Now several new surveys, based on cores of annual growth rings, show unprecedented patterns of retarded growth that set in within the last 20 years. The damage is worst at remote mountain peaks, which are often bathed for days in acid clouds. Biologists cannot yet prove acid rain culpable, but the likelihood adds urgency to the already formidable case for tackling the acid rain problem.

The Reagan Administration's undeviating policy is to do nothing about acid rain except study it. The callowness of its understanding emerged in budget director David Stockman's scoff that the cost of reducing acid rain would amount to $6,000 per pound of fish saved.

But the dead fish are merely one symptom of the invisible stress that presses on the ecology of the entire Eastern Seaboard. The study commissioned by Mr. Reagan's science adviser has already concluded that action on acid rain should begin, despite incomplete knowledge. Other scientific reviews, including two by the National Academy of Sciences, point to the same conclusion.

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The basic solution — cutting emissions of sulfur dioxide by half — would require power plants in the Midwest to switch to low-sulfur coal or install scrubbers. The political problem is how to pay for the switch and its dislocations.

William Ruckelshaus, the head of the Environmental Protection Agency, had intended to tackle the acid rain issue. "I would like you . . . to meet this issue head on," Mr. Reagan said at his swearing in last May. But the President's heart wasn't in it. In October he let Mr. Ruckelshaus's plan be overruled. The White House has reverted to its old, uncomprehending line that more studies are needed.

An issue as complex as acid rain can be studied forever. A stressed ecosystem can collapse overnight once its resilience is exhausted. That has already happened to parts of West Germany's Black Forest. Any acid rain program will take at least five years to cut heavily into sulfur dioxide emissions. That's why so many studies have recommended action now.

The new studies Mr. Reagan wants will provide only further delay, not a different answer.

ASSESSING THE EFFECTS OF ACID RAIN ON FORESTS OF THE EASTERN U.S.

Testimony Before the United States Senate
Committee on Environment and Public Works

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February 7, 1984

Determining the effects that deposition of acidic substances has had or will have on forests requires an understanding of the direct effects acidic substances have on plants, and the indirect effects which might alter soils or soil-mediated processes. There has been a substantial number of experimental and theoretical research projects which have given us mixed signals about what acid deposition can do. Results of the experimental work indicate that simulated acid rain can have negative effects, positive effects, or no effect on the growth, germination, or resistance to disease of forest trees, but we do not have the appropriate nutritional or physiological information to understand why the effects were observed. We cannot, at present, confidently assess what is actually happening or what might happen in our forests based on the experimental results because we lack detailed process-level information, because the experimental acid applications are not uniform in producing benefit or harm, and because the experimental conditions are simple compared to the complex of factors which controls the growth; reproduction and health of trees in the forest.

We have some interesting results from empirical studies of trends in tree growth and mortality and statistical analysis of the relationship of the growth rate patterns to natural phenomena and to patterns of pollutant emissions and deposition. The results of these types of investigations have shown that in a large number of cases, the growth of forest trees has been substantially less than expected during the past 15 to 25 years, and that in a few cases, mortality has been substantially greater than expected. In relatively few cases has growth been greater than expected. The generalities cited above are the result of data which has been gathered by a number of scientists from measurements of tens of thousands of trees in thousands of plots in 14 states east of the Missisippi. The unexplained reductions in growth and/or increases in mortality have been observed in six or seven coniferous species in Maine, New Hampshire, Vermont, New York, New Jersey, Virginia, Tennessee, North Carolina, South Carolina, Georgia, and Alabama. I hasten to add that the factors which are involved in these phenomena are presently not known; they may be different in different areas, and the role, if any, of acid rain has not been identified.

The findings in North America have been derived from studies of tree rings carried out by many investigators in many locations, and from repeated measurements of tree diameters carried out largely by the U.S. Forest Service. Tree ring studies conducted in central and northern Europe have shown the same anomalous patterns in diameter growth rates in recent decades, followed by alarming incidences of decline and mortality in several species.

Because the changes are substantial (growth rates of 10-40 percent less than expected) and cover broad geographic areas of aesthetically and commercially valuable forests, identification of the cause or causes of these unexpected trends in growth and mortality should be a high priority. Because these changes have been identified in areas receiving moderate to heavy rates of acid deposition, and because the changes occurred during a period when acid deposition has intensified and spread, considerable speculation exists as to how acid rain might be involved. The current state of our understanding based on sound scientific investigations is as follows:

1. **Substantial and easily visible changes in growth have been identified in tree ring studies of some conifers across their ranges in the eastern U.S.** This phenomenon is well documented in 8 states and three species, pitch pine, shortleaf pine and red spruce. Preliminary indications are that this phenomenon is apparent in other species of conifers. The change to abnormally small yearly growth increments is generally rapid and is observed in a substantial proportion of the populations. This change to reduced growth apparently signals the onset of stress, and it occurs after 1955, but in different years in different trees. Trees in all age classes are affected. We have been unable to explain this rather synchronized, regional and long-lasting effect solely on the basis of natural growth-controlling factors such as weather patterns, drought, temperature anomalies, competition, disease, insects, or catastrophic events such as ice storms, hurricanes, etc. It is reasonable to suspect that airborne pollutants alone or in combination with natural stresses could be involved.

2.**Forest Survey data from the Piedmont region of the southeastern U.S. show very clearly unexpected, reduced growth of economically important conifers in the 1970's compared to the 1960's.** These findings are new, and the meaning of this reduction in growth and the factors responsible are not known. The two most important timber species in the South, loblolly and slash pine show inexplicably low growth rates across all of the Piedmont in Alabama, Georgia and South Carolina.

3. **Unexplained, massive mortality has occurred in red spruce in high elevation forests of the Appalachians.** This type of mortality has been documented in North Carolina, New York, Vermont, and New Hampshire, and will likely be clearly identified in other areas soon. Whether or not anomalous mortality has occurred in other species of the high elevation forests is uncertain at present.

4. **The high-elevation forests of the eastern U.S. are subject to extremely high rates of acid deposition, and other airborne substances compared to low elevation forests of the East.** The high rates of input result from high rainfall amounts and prolonged, frequent contact with clouds which cap the mountains. The substances for which we have adequate documentation include sulfuric acid, acidifying nitrogen compounds and heavy metals, particularly lead. Thus by comparison to most of the forests in the east, the remote mountain peaks of the Appalachians are highly polluted environments.

4. **Determining whether or not the mortality in spruce and the anomalous growth trends are related to acid deposition or other pollutants is complicated by several factors.** At this time, no symptoms attributable to a specific pollutant or to a specific type of failure in the plants have been identified. We do not know how resistant the plants or the ecosystems are to ambient doses of the individual pollutants, or combinations of pollutants, or how pollutant and natural stresses interact. We are currently unable to conclusively rule out natural stress as a primary cause in most of the cases.

5. **There is currently no consensus among the scientific community about the involvement of acid deposition in the anomalous growth and mortality patterns observed here and in central Europe.** I stress that there is no clear evidence that acid rain is involved, and there is no clear evidence that acid rain is not involved. It is an open question. I suggest that any political decisions made with our current level of understanding should take into account that recent trends in growth and mortality are, in many cases unfavorable, that these trends have been identified in areas receiving a mix of pollutants including acid rain, and that the sum of the evidence suggests that airborne pollutants are reasonable possiblilities as major contributors. Convincing evidence regarding the involvement of sulfur emissions could emerge from ongoing and planned research, but that evidence is not presently in hand.

Testimony on Regional Changes in the Growth and Behavior of Forests in Central Europe and Eastern North America

by

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Prepared for Public Hearings by the United States Senate
Committee on Environment and Public Works
Room 410, Dirksen Senate Office Building
Washington, D.C. 20510
9:00 a.m. - Tuesday, February 7, 1984

Statement by Dr. Ellis B. Cowling, Associate Dean for Research,
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Prepared for Hearings on the causes and effects of acid deposition by
United States Senate Committee on Environment and Public Works.

Introduction:

For the past 24 years, I have been a professor of Plant Pathology and Forest Resources at Yale and North Carolina State Universities. During the past 14 years, a significant part of my educational, research, and administrative efforts has been aimed at the development of a more adequate understanding of changes in the chemical climate of North America and Europe and their effects on plants, animals, surface waters, and materials.

Since 1976, I have led a group of nearly 200 scientists in 50 institutions and agencies in the United States and Canada in establishing the National Atmospheric Deposition Program (NADP). The NADP is an interregional project (designated IR-7) of the State Agricultural Experiment Stations, various federal agencies, and private industries. Its major purposes are to: 1) encourage and coordinate research on the biological and other consequences of air pollution and atmospheric deposition; and 2) to establish a long-term monitoring network to measure chemical changes in the chemistry of rain and snow in various parts of the United States.

Since the fall of 1977, I have been active in the National Acid Precipitation Assessment Program. Since the fall of 1981, I have served as the United States co-chairman of the Triacademy Scientific Committee on Acid Deposition. In this and other roles with the National Academy of Sciences I have assisted in the development of the so-called

"Atmosphere-Biosphere Report" which was issued in 1981 and the so-called "Calvert Report" which was issued in 1983, I am very pleased to commend these reports for careful study by the Congress.

Since August 1979 I have served as Program Director for a Cooperative Agreement between the Environmental Protection Agency and North Carolina State University. The purpose of this Agreement is to provide EPA with an improved understanding of the effects of acid deposition on aquatic and terrestrial ecosystems. This Agreement provides a major linkage between the National Acid Precipitation Assessment Program and the community of university scientists who are actively engaged in research on the biological and water-quality effects of acid deposition in the United States.

Two of the most important outputs from this Agreement are a series of Critical Assessment Review Papers and an Integrative Critical Assessment Document summarizing the present status of knowledge about acid deposition and its environmental consequences. In his testimony before this committee last Tuesday, EPA Administrator William Ruckelshaus referred to these reports as"the most definitive integration and synthesis to date on the full range of issues critical to acid rain."

During the fall of 1983, I was invited to travel to West Germany for the purpose of assessing the recently developed decline of forests and to further encourage the development of a small working group of scientists in West Germany and the United States who:

a) will lead a multidisciplinary program of research to identify testable hypotheses about the causes and management of the dieback and decline of forests in the two countries; and

b) are willing to maintain effective liaison among government, industrial, and private forest organizations in the two countries with concerns about changes in the chemical climate and their effects on the productivity of forests.

I am proud to say that my colleague in testimony before this Committee, Dr. Arthur Johnson, will provide scientific leadership for this important scientific dialog with West Germany.

My testimony at these Hearings has been requested because of my knowledge and experience as a scientist. Thus, the ideas described here and in my verbal testimony before the Senate Committee are my own and may or may not be coincident with the policies and attitudes of the institutions and organizations with which I am affiliated.

Attachments:

Attached to and forming a part of this written testimony are several items which may prove helpful in understanding regional changes in the growth and behavior of forests and their relationship with air pollution and acid rain in central Europe and eastern North America.

Item 1) A report entitled "Observations in German Forests During the Late Summer of 1983." This report summarizes the results of a series of observations and consultations in West Germany that demonstrate, to my satisfaction, that scientifically unprecedented changes in the appearance and behavior of forests are taking place in large parts of Germany and other countries in central Europe.

Item 2) A list of available German-language publications illustrating the remarkable array of disease symptoms which are described in Items 1 and 3 and which provide the background for understanding and investigating possible causes of the widespread decline of forests in central Europe.

Item 3) The first three pages of a draft manuscript prepared in January 1984 by Dr. Peter Schütt, Professor of Forest Botany and Pathology at the University of Munich. This manuscript is intended to provide the first comprehensive English-language description and illustration of the symptoms of "Waldsterben--a general decline of forests in central Europe." Please note especially the statement on page 2 of Professor Schütt's draft paper which reads as follows:

> "There are a number of special facts and observations which make the Waldsterben-syndrome a pathological phenomenon standing apart from ordinary tree diseases. ... They lead us to the impression that the syndrome is going to destroy the forest as an ecosystem. On the other hand, we become more and more nervous because we are forced to learn more about the pathogenesis and primary causes before we get a realistic chance to stop a beginning catastrophy." (Underlining for emphasis by Ellis Cowling).

Item 4) A report of recent observations and experimentation relating to an unexplained decrease in growth, dieback, and decline of red spruce and a similarly unexplained inhibition of reproduction of all trees and shrubs on the summit and adjacent ridges of Mount Mitchell in western North Carolina. Mount Mitchell has special significance for the nation since it is the highest peak in all of eastern North America. This report was prepared by two colleagues in forest pathology at North Carolina State University--Professor Robert Bruck and his PhD student Sandy

Meier. These observations are in part similar to and in part dissimilar from those reported from Germany in Items 1-3.

Item 5) Reprint of a paper on "Discovering the Causes, Consequences, and Implications of Acid Rain and Atmospheric Deposition." This paper was published in September 1983 in TAPPI--the journal of the Technical Association of the Pulp and Paper Industry of the United States. The principal message of this paper is summed up in its by-line:

> "The forest products industry must think of itself as a net receiver rather than a primary emitter of air pollution."

Item 6) A list of four questionable assumptions underlying the Clean Air Act of 1970 and its amendments of 1977. This list was prepared originally for hearings on acid rain by the United States Senate Committee on Environment and Public Works in May 1982. This item was deleted from my testimony at that time on the assumption that these ideas might find more meaningful reception in later hearings dealing more specifically with possible revisions of the Clean Air Act.

General Comments and Conclusions:

The various papers and reports contained in the attachments to this testimony and the testimony of my colleague, Dr. Johnson, lead to the following general comments and conclusions:

1) Beginning in the late 1970's, economically valuable forests containing 10 different species of hardwood and softwood trees showed a very rapid and scientifically unprecedented series of symptoms in large parts of West Germany and nearby nations of central Europe.

These remarkable symptoms of stress include decreased growth; thinning of foliage; abnormal patterns of shoot, foliage, and root development; abnormal reproductive behavior; and decline and eventual death of trees, shrubs, and herbaceous vegetation. These symptoms are shown by trees growing at high and at low elevation; on nutrient-rich and nutrient-poor soils; on acid soils and basic soils; in natural stands and in planted stands; in mature forests of 80-140 years, middle age forests of 40 to 60 years, and young sapling stands of 5-20 years.

2) It is widely assumed (and I think correctly so) that air pollutants and/or acid deposition are among the stress factors that have caused or are contributing to the symptoms observed in the forests of central Europe. But this idea is still only an hypothesis; it has not been proven unequivocally.

3) Changes in the growth and behavior of softwood forests have also been observed recently in various parts of eastern North America. A consistent and simultaneous decrease in rate of growth since the early 1960's has been reported in red spruce, shortleaf pine, and pitch pine. Both young and mature stands of red spruce have also shown a progressive dieing back from the top, particularly at high elevation. The area of affected spruce forests extends from southeastern Canada to the southern Appalachian Mountains. At the summit of Mount Mitchell, reproduction of both red spruce and Frazier Fir and all woody shrubs was found to be inhibiited above about 6,350 feet in elevation.

4) It is widely assumed (and I think correctly so) that air pollutants and/or acid deposition are among the stress factors that have caused

or are contributing to these symptoms in eastern North America. But this idea, like those pertaining to central Europe, is still only an hypothesis; it has not been proven unequivocally. It should also be recognized that the concentrations of sulfur oxides in many parts of Germany are substantially greater than those in areas where forest effects have been detected in eastern North America.

5) In recent years, the term "acid rain" has captured the imagination of the people of the United States, Canada, and Europe. This has come about in part because of the now well established contribution of sulfur and nitrogen oxides to the acidification of surface waters, the mobilization of toxic metals, and related effects on fish and other forms of aquatic life in certain sensitive regions of northern Europe and eastern North America.

6) These detrimental effects of aquatic ecosystems due to wet and dry deposition of acidic and acidifying materials from the atmopshere are caused in large part by emissions from combustion of fossile fuels and smelting of metal ores. Utility and other industrial boilers, metal smelters, transportation vehicles, and residential and commercial space and water heating are the most important sources of sulfur and nitrogen oxides which lead to wet and dry deposition of acid substances. But they are also major sources of other air pollutants including: fluoride, the precursors of ozone and other photochemical oxidants, toxic metals, unburned hydrocarbons, and many other volatile organic compounds.

7) The net beneficial and detrimental consequences of these emissions include the following:

   a) fertilization of crop and forest land with nutrients that are essential for plant growth and development;

b) increased haziness and decreased visibility in urban, surburban, rural, and even remote areas;

c) increased corrosion of metals and accelerated weathering of stone and masonry materials in buildings, sculpture, engineering structures, and historical monuments;

d) increased respiratory and other diseases of human beings;

e) increased contamination of drinking water supplies by gases, aerosols, and particulate chemicals (including acids, toxic metals, and volatile organic materials) by deposition from the atmosphere or leaching from the soils and bedrock of watersheds;

f) increased damage to crops and forests by toxic gases such as ozone and sulfur dioxide and perhaps also by atmospheric deposition of acidic and acidifying substances;

g) loss of fish populations and other forms of aquatic life in sensitive surface waters.

8) It is now widely accepted that any substantial change in national or regional emissions of sulfur and/or nitrogen oxides will lead to an approximately corresponding change in amounts of deposition and an attendant change in the several societal costs and benefits listed under item 7.

9) Energy conservation, and decreased use of energy and materials, are essentially the only means by which significant decreases in emissions and deposition of acids, toxic metals, photochemical oxidants, and other injurious air pollutants can be achieved in the absence of major changes in the emissions standards of the United States and Canada. The recent voluntary decision of the Tennessee Valley Authority to achieve a 1,000,000 ton per year

decrease in sulfur oxide emissions stands as a notable exception to this general conclusion.

10) Even if a decision were reached in 1984 or 1985 to mandate significant decreases in sulfur oxides or other emissions, it probably will take at least 5 years to develop specific state, regional, national or international implementation plans to achieve the required decreases. Also, at least another 5 years probably will be required to design and build the machinery and control systems necessary to achieve the targeted decreases in emissions. During this at least 10-year period of debate, planning, engineering design, and evaluation, new biological, atmospheric chemical, meteorological, and climatological insights will be developed which will help refine whatever management strategies may be recommended. Therefore, it seems prudent that the United States begin the planning and evaluation procedures now, recognizing that research is continuing and that the earliest possible date for achievement of significant decreases in emissions (except through energy conservation and decreased use of energy and materials) will be the mid-1990's.

Summary

Our present energy and environmental policies are resulting in continuing change in the chemical climate or North America and Europe. Important changes are taking place in the lakes, streams, fields, and forests on which both the abundance and the quality of human life depends. Wise management of these resources requires knowledge and communication among biologists, hydrologists, atmospheric chemists, meteorologists, climatologists, regulatory strategists, and both industrial and political leaders in the United States and Canada.

Let us continue that communication by focusing our collective knowledge and good judgement in the development of more adequate plans for management of air quality and its effects on human health, crops, forests, animals, soil surface waters, and materials. The current debate about possible revision of the Clean Air Act is one of the most important occasions for such collective thinking.

CURRENT STATUS OF RESEARCH IN ACID RAIN[1, 2]

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ABSTRACT

Studies on acidic depositions have been directed towards an assessment of the possible deleterious effects of both wet and dry depositions on many aspects of human, structural and biological systems. Without exception, complete information is not available on any facet of the acid rain problem although considerable research progress has been made over the past decade.

The evidence strongly implicates the combustion of fossil fuels and the smelting and refining industries as primary sources of atmospheric sulfur and nitrogen oxides. Fossil fuels and the metal industries are sources for depositions of a variety of metals. The transport, transformation, and deposition of these anthropogenic pollutants is under active investigation. Eastern North America, the midwest, Ontario and Quebec, are implicated as the sources.

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[1] Presented at the Technical Symposium on Acid Rain: Transport and Transformation Phenomena, the 1983 George D. Aiken Lecture Series, University of Vermont, 22 September 1983.

[2] Research supported by the Vermont Agricultural Experiment Station; the Northeast Forest Research Laboratory, U.S. Forest Service; the Water Resource Research Center, University of Vermont; the Texaco Foundation; the Jackson Hole Foundation; the A.K. Mellon Foundation; the R.K. Mellon Foundation; and the American Electric Power Service Corp.

[3] Co-directors of the Botany Department's Acid Rain Research Project and Professors of Botany.

Human health aspects are receiving limited attention. Particulates, particularly of sulfate covalently bonded to cations, increase local hazes, reduce visibility and can be respired. Susceptible individuals may experience breathing difficulties and inadequate animal studies have suggested that the smaller particles can be retained in lungs and bronchae. Long-term effects of retention and conversion of salts into free acids in tissues has not been well studied.

In many rural areas, household and farm water is derived from springs, shallow wells or small municipal water supplies whose water comes from mountainous watersheds receiving acidic depositions that have solubilized endogenous and deposited metals such as aluminum, cadmium, lead, zinc, and possibly vanadium, arsenic and other elements. Acidic water can also leach lead, copper and other metals from piping. The composition of home and farm water in areas where it is derived from mountainous watersheds is virtually unknown as are actual or potential effects on humans and animals.

The evidence is overwhelming that acidic depositions are causing deterioration of man-made structures and materials. Acid-attack of metal bridges, stone monuments and buildings, tombstones, etc., is widespread. Research on the problem in North America is slight, although destruction of important structures which are part of the world's cultural heritage occurs in many countries. Restoration, repair and protective procedures are not well worked out, cost estimates are high and variable.

Damage to fresh-water ecosystems was among the first to be adequately evaluated both in field and controlled laboratory studies. The influx and direct deposition of acidic, metal-containing water into streams, ponds and small lakes have been studied for over twenty years with results that unequivocally demonstrate that anthropogenic pollutants, frequently carried for hundreds of kilometers, are the direct cause of death of vertebrates, invertebrates and plants, including microorganisms. The proximate cause of the death of the biota is a combination of acids and metals. Available evidence, incomplete but compelling, suggests that death is due primarily to alteration in the integrity of cellular membrane systems that regulate the flow of gases and soluble compounds into and out of cells. Studies on alteration of enzyme systems including the respiratory and photosynthetic pathways are currently inadequate, few current studies are directed towards and evaluation of possible genetic responses to the increased cellular burden of metals.

Damage to aquatic ecosystems appears to be progressive over time; biotic destruction depends upon geology, the quality and quantity of aquatic life and other factors. There is, however, adequate evidence that deterioration of aquatic environments is directly traceable to acidic depositions and can be measured with reasonable precision in situ. Attempts to select or breed for resistance in both plants and animals are underway, but have not been uniformly successful. Alkali or lime treatments of lakes are palliative, of short duration, and may be ecologically and physiologically contraindicated.

Research on responses of terrestrial ecosystems to acidic deposition is less complete than for aquatic systems due to their greater turnover time (measured in a century or more) and their greater complexity. The best data base in North America, that of Camels Hump Mountain studied by our group, is less than twenty years old and no obvious control site free of acidic deposition exists in the northern, highly industrialized hemisphere.

Available evidence for alteration of agricultural potential indicates that well-managed lands are not now at serious risk. There is no consensus on reduction in yields of important agricultural or horticultural crops; reported damage under realistic experimental conditions does not appear to be economically important. Long-term effects on managed agricultural soils have not been reported, but are likely to be minimal.

Uncultivated and forest ecosystems appear to be at great risk and evidence is mounting that severe and possibly irreversible damage has already occurred. The more dramatic destruction seems to occur above 2000 feet on west-facing slopes, although damage to tree species at lower elevations is no less significant. We and others have quantitatively measured death of economically important species including sugar maple, beech and possibly ash at lower elevations while death of important conifer species -- red spruce and balsam fir -- is impressive at higher elevations. There are reductions in moss cover that may affect erosion control, decomposition of litter that affects nutrient cycling, and degree of mycorrhizal associations that modify water and mineral uptake by trees. Water relations of trees are seriously altered by combined acid and metal ions in soil water, seedling root growth is affected negatively and reproductive failure on red spruce is evident. There is mounting evidence that the growth rates of forest tree species has declined. Combined laboratory and field studies are fully and solely consistant with the hypothesis that acidity and solubilized metals are the proximate cause of the deterioration of natural forested ecosystems. There are clear implications for recreation, watershed management, timbering and other economic and social activities.

Although anthropogenic production and precipitation of acids probably existed since humans discovered fire and certainly since civilizations became industrialized, long-distance dispersal appears to be a modern phenomenon. Other participants in these Lectures have discussed the transportation and transformation of anthropogenic pollutants. There is now a significant load of acids and other substances in wet and dry depositions reaching land and water surfaces of many parts of the world. Primary to any evaluation of the "acid rain" problem is whether there is demonstrable damage caused by these depositions, the degree and permanence of damage if it exists and whether amelioration or reversal of damage is environmentally and economically possible. There is now no question that damage represents a "clear and present danger," and that some damage may be effectively permanent. This brief and wide-ranging survey will attempt to justify these broad conclusions in terms of the current status of research.

Irrespective of how they arrive and from where, acidic rain, snow, cloud water condensates, rime ice, and dry depositions are the norm throughout most of the industrialized regions of the world. The acidic constituents are primarily sulfuric and nitric acids. Excepting small amounts of acids produced naturally by bacterial metabolism, from sea sprays, volcanoes, etc., acidic depositions are anthropogenic. Physico-chemical and meteorological factors interact to facilitate widespread dispersal, extending hundreds of kilometers from sources. Acidic deposition also may include gaseous pollutants (ozone, sulfur and nitrogen oxides, organics, etc.) known to interact with acids in causing biotic damage. The metal industries -- extraction, smelting, refining and fabricating -- and fossil-fuel combustions contribute significant quantities of heavy metals that have accumulated in ecosystems.

The yearly weighted average of rain pH in upper New England is now close to 4.2 with single storm events showing pH values of 3.5 or lower. Ancient glacial ice has pH values of 5.2 to 5.5 compared with the pH of 5.7 of pure water in equilibrium with carbon dioxide. Thus, current precipitations in the eastern United States and adjacent Canada are at least 10-20 times more acid than those unaffected by human activity and in many cases are closer to 40 times more acidic. It is important to note here that cloud (fog) water impinging on elevated ecosystems has a weighted average pH value five times that of rain or snow, and early snow melt is an order of magnitude more acidic than the bulk snow.

There is, then, a significant influx of hydrogen ions and associated anions plus variable quantities of other biotically active substances. It is of great significance that wet and dry acidic depositions also carry metals including arsenic, cadmium, copper, germanium, lead, vanadium and zinc emitted by industry, vehicles and home activities. These deposited metals plus endogenous aluminum and other metals are solubilized by acidic depositions and are found in biologically significant amounts in soil and ground water, in streams and in ponds and lakes. Were acid rain solely a dilute sulfuric-nitric mixture, it would be biologically significant, but the presence of dissolved metal ions makes acidic deposition even more stressful to organisms.

Questions relating to the effects of acidic depositions on public health are currently unanswered, due to inadequate field, epidemiological and laboratory simulation studies. Two aspects of health must be considered. Particulates, particularly covalently bonded sulfate, forms obvious hazes and can be respired. Those at the micron and sub-micron range can enter bronchi and alveoli and serve as irritants. People with respiratory disorders have reported asthma episodes, but epidemiological relationships have rarely been evaluated nor is there firm evidence for or against conversion of these particulates into free acids in the lungs.

There is a large body of evidence showing that metals are toxic to humans. Our studies and those of others, have shown that endogenous and deposited metals in mountainous regions are being solubilized by acidic depositions and can become part of both soil and ground water. Indeed, as I will note later, one proximate cause of aquatic damage is the introduction of metals into ponds and lakes. In New England, rural families obtain their drinking water from springs or shallow wells fed from mountainous watersheds. To my knowledge, such water supplies have not been monitored for acidity or for metals, nor have plumbing systems. In soil and ground water from some mountains, the concentrations of metals is high enough to be a potential danger to children and to the elderly. The known relationships between neurological disorders and metals and the well-substantiated capacity of metals to bind to proteins and nucleic acids has not received attention in relation to acid depositions.

The effects of acidic depositions on structures and materials has received considerable attention, although the topic is more complex than has generally been believed. Deterioration is caused by pollutants, heavy vehicular traffic, neglect as well as age, and acidic depositions are only one part of the story. Well-publicized figures on the causes and costs of deterioration are generally guesstimates although there is reasonable assurance that acidic depositions are involved. There is adequate data from chemists and engineers that acids attack bridges, monuments, buildings, gravestones, etc. There has been excellent theoretical and applied research on repair and restoration of structures, although much more will be needed as deterioration continues. To date, however, the efforts of engineers and preservationists have not been correlated nor has their interaction been fostered. An adequate compilation of the extent or severity of damage in social, historical or economic terms is unavailable. Nevertheless, we cannot conceive of deriving a monetary cost-benefit ratio for the Parthenon, the House of Parliament in Ottawa, the Lincoln Memorial, or Camels Hump Mountain.

If anything brought acid rain to public attention, it was the well-publicized assertions that acid depositions were "killing lakes." First reported in Scandinavia several decades ago, the discovery that North American lakes were devoid of fish, most invertebrates, and many plants was dramatic, headline-catching and, unfortunately, true. Excellent fundamental research in Europe and later in North America, has provided a coherent and scientifically acceptable scenario that is now, particularly on the west coast, being studied in the act.

In bodies of fresh water with low buffering capacity -- those on granite rock for example -- acidic spring snowmelt provides a rush of polluted water capable of swamping or overwhelming its buffer capacity, at least for a period of time. Lake pH drops below 5.0 or 5.5, values that are toxic to fish eggs and young fry. Many aquatic organisms can withstand pH 5.5, but are incompacitated and their young killed at pH values below 5.0. There are species differences with salmonoids being quite susceptible. Adults can withstand the hydrogen ion insult, but succumb to the combined assault of low pH and metals dissolved in this meltwater. Death is primarily, but not exclusively due to alterations of the gill aparatus that exchanges oxygen and carbon dioxide with the water. Water plants also exchange gases with their environment and must take up water and minerals, apparently die because of alterations in their cellular membranes Sphagnum mosses and acid tolerant algae proliferate in acidic lakes and become the dominant and sometimes the sole life forms.

Palliative liming of lakes to raise pH and precipitate metals is a Band-aid approach because lime or alkali treatments must be repeated almost yearly and there is accumulating evidence that lime has long-lasting side effects.

There is general agreement on the direct relationship between acidic depositions and damage to aquatic ecosystems, but there is much less agreement about whether acidic depositions are affecting terrestrial ecosystems. Managed lands, including those used for agriculture, horticulture and for tree plantations, do not now seem to be at serious risk. Such lands are regularly fertilized and their acidity adjusted. Modern cultivars of food, fiber and other crop plants have involved hundreds of years of selection to develop adaptable cultivars and modern breeding programs have extended the tolerance of cultivated plants. There are conflicting reports of damage to important legume crops, but yield reductions, if they do occur, are small unless the imposed acidic loads are beyond present levels. This agronomic research is important for predictive purposes and is somewhat analogous to the massive dose concept underlining testing of medicinal drugs or food additives.

Managed lands can be studied fairly easily; most crop plants are annuals or biennials so that turnover time is short. Agricultural ecosystems are relatively simple and uniform and moderately controllable experiments can be conducted under field conditions. This is not true for unmanaged lands and mountainous ecosystems where environments separated by less than a meter may be different. The widespread occurance of acidic deposition severely limits comparison studies and the mind-boggling diversity of interacting biotic and nonbiotic components reduces the possibility of designing adequate field experiments. Our field-data base is probably the best in North America, but it extends back only to 1965 -- at least 15-20 years after the inception of widely dispersed acidic depositions. Clearly, such strictures prevent us from ever providing the political process with the certainty that they -and we- would like.

Nevertheless, studies of research groups in North America and Europe have amassed a great deal of pertinent information from which reasonable probability predictions can be made. The conclusions are based on both field studies and on laboratory simulations designed to isolate one possible factor in the complex as highlighted by field studies. While simulations are fraught with obvious dangers, the noise in the field is too great -- acid rain research becomes an uneasy compromise.

Although North American forests are not receiving the level of acidic depositions seen in Europe, well-studied areas in Vermont and New York are showing the same sequence of events and the same decline syndrome. Put simply, the Camels Hump ecosystems in Vermont is a catastrophy in progress, and both our field and our laboratory studies are fully and solely compatible with the working hypothesis that the declines are due largely to the combined actions of acids and solubilized metals.

Some field and laboratory data will illustrate this contention. There are two major ecosystems on Camels Hump: a northern hardwood forest dominated by sugar maple and beech at the lower elevations and a balsam fir - red spruce northern coniferous forest at the upper elevations. Dominant and sub-dominant tree species have shown extensive death since 1965. Reproductive failure is evident for red spruce. Mosses that carpet the surface have decreased in coverage in both ecosystems by fifty percent and the litter on the forest floor is decomposing at half the expected rate. Windthrow of dead trees has made much of the forest an almost impenetrable tangle. We know that rain, snow, cloud water, and rime ice are acidic, contain metals and that the burden of metals in the soils is significantly greater than in 1965. All these are facts substantiated by statistically acceptable data. The question of whether these biotic alterations are due to acidic depositions is the one at issue. To evaluate this possibility, we have turned to laboratory simulations.

Briefly, our laboratory experiments are in agreement with our hypothesis. Combined acid metal treatments of forest litter reduce significantly the decomposition of litter, depress the growth of one of the dominant moss species isolated from Camesl Hump, decrease litter decomposition, and increase the leaching of nutrients from litter. Acidic mists increase the leaching of nutrients from leaves and needles of forest trees. Current research indicates that combined acidic and metal ion exposure of young spruce and fir trees decreases the ability of the trees to take up and move water and minerals, which alone can cause declines in growth and development. Hydroponic experiments demonstrate that ecologically-realistic acid-metal combinations can be lethal.

Dendrochronological studies on spruce, fir, sugar maple and several species of birch are in progress to assess the important question of declines in growth rates of these ecological and economically important trees. The study also includes chemical determinations of the chronology of metal deposition in wood. Significant deposition of germanium, aluminum, iron, manganese, and vanadium have pinpointed the advent of metal-solubilizing precipitations starting in the 1940-1950 period. Arsenic accumulation started around the turn of the century. Whether these metals are modifying the cellular processes that result in growth reductions is probable, but not proven.

An unequivocal demonstration, one that can stand up in the courts and the political arena, is not yet available. The working hypothesis that damage to terrestrial ecosystems is caused by damage or alteration of a number of components that interact in such ecosystems has been obtained by quantitative studies of selected ecosystems stressed by industrial pollutants such as Camels Hump, Sudbury, Ontario, and Germany's Solling forests, and by reductive laboratory simulations of ecosystem components. Attempts to derive an alternative hypothesis consistant with all available facts -- as does exist for the hypothesis of acid-metal interactions -- have not been successful. Hypotheses based on a drought, insect or disease etiology are grossly inadequate, although drought certainly can be a contributing stress factor explaining some but not all of the observed and simulated alterations. Inadequate evidence and illogical interpretations mitigate against acceptance of a drought causation much as this would please some sectors of the economy.

It does not seem possible to us that the course and rate of terrestrial or aquatic ecosystem deterioration is capable of being slowed, stopped or reversed without very large reductions in the emission of acidic and metal-containing substances. The costs are reasonable and bearable and the public has indicated its willingness to assume these costs, directly or through taxes. Of course, additional information is required and will, in due course, become available. The major question is, however, whether more than enough evidence is available now to permit the political and economic sectors to act? The peoples of the world have made much harder decisions and choices with much less evidence.

CAMELS HUMP - ABOVE GROUND BIOMASS ESTIMATES BY FOREST ZONE (All Tree Species > 2cm)

Year of Measurement	1965	1979	1983	% change '65-'83
HARDWOOD (1800-2400 ft)	269,871	238,684	218,208	- 19%
TRANSITIONAL (2600-2800 ft)	135,175	145,335	119,983	- 12%
BOREAL (3000-3800 ft)	142,520	113,877	84,217	- 41%

ABOVE GROUND BIOMASS BY TREE SPECIES (>2cm)

	Kilograms per hectare ($\bar{x}$)			
	1965	1979	1983	% change '65-'83
Sugar Maple (Acer saccharum Marsh)	135,584	114,860	102,937	- 25%
Beech (Fagus grandifolia Ehrh.)	66,695	46,621	49,997	- 25%
Yellow Birch (Betula lutea Michx.)	39,876	51,137	45,851	+ 15% (-10 since '79
Red Spruce (Picea rubens Sarg.)	30,381	17,373	8,698	- 71%
Balsam Fir (Abies balsamea L.Mill.)	51,763	48,521	41,948	- 19%
White Birch (Betula cordifolia Regel.)	30,253	34,915	19,817	- 34%
Mountain Maple (Acer spicatum Lam.)	1,672	714	647	- 61%
Striped Maple (Acer pensylvanicum L.)	978	744	753	- 23%
Mountain Ash (Sorbus americana)	1,755	1,514	1,071	- 39%

Changes in litter depth between 1965 and 1982 and changes in percentage organic matter in the 02/A1 horizon between 1965 and 1979 in ecological zones of Camels Hump Mountain in the Green Mountains of Vermont.

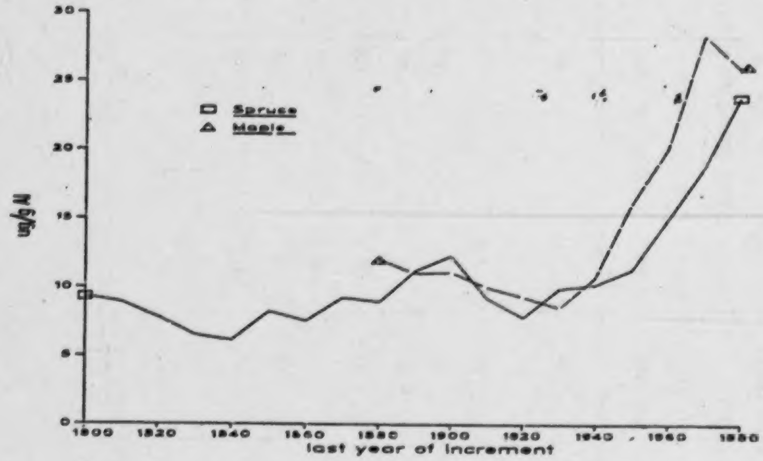
Zone and Elevation	Litter Depth (cm) 1965	Litter Depth (cm) 1982	1982 as % of 1965	% Organic Matter 1977	% Organic Matter 1979*	1979 as % of 1965
Hardwood 550-730 m	3.5±0.45[†] (n=12)	7.3±1.5 (n=12)	210	35.2	53.8	153
Transition 730-850 m	3.8±0.45 (n=6)	7.1±1.7 (n=27)	180	51.8	94.2	182
Boreal 850-3800 m	4.5±1.7 (n=12)	7.8±1.7 (n=54)	170	62.8	99.5	161

*Unpublished data courtesy of Dr. Thomas Siccama

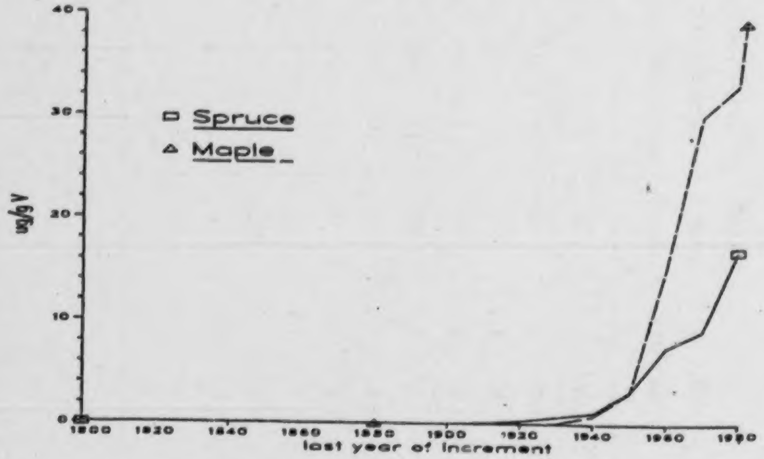
[†] ± standard deviation

Coverage of Surface Soil by all Mosses on Elevations of Camels Hump Mountain, Vermont.

ZONE	ELEVATION (m)	SOIL pH		No. 1-m^2 QUADRATS EXAMINED	m^2 QUADRATS WITH MOSSES			AVERAGE % COVER OF QUADRATS CONTAINING MOSSES			MOSS COVERAGE OF ALL QUADRATS		
					NUMBER		1979 as %			1979 as %	% in	% in	1979 as %
		1965	1979		1965	1979	of 1965	1965	1979	of 1965	1965	1979	of 1965
HARDWOOD	550	5.3	5.4	60	22	31	140	16	7	44	6	4	67
	610	6.0	5.1	60	18	37	205	17	4	24	5	3	60
	670	4.8	4.9	60	11	23	209	21	6	28	4	2	50
	730	4.5	4.3	60	9	19	211	32	6	32	5	2	40
TRANSITION	790	4.0	4.7	60	16	22	137	19	3	16	5	1	20
	850	3.7	4.1	60	36	40	111	36	12	33	21	8	38
BOREAL	915	3.6	3.9	30	19	23	121	40	13	26	31	10	32
	980	3.6	3.9	30	21	23	110	42	40	95	29	31	107
	1040	3.7	3.9	30	21	19	90	35	34	97	24	21	88
	1100	3.5	3.8	30	22	22	100	22	15	40	27	11	41
	1169	3.6	3.9	30	23	23	100	61	26	43	47	20	43



Aluminum in Camels Hump Red Spruce and Sugar Maple



Vanadium in Camels Hump Red Spruce and Sugar Maple

STATEMENT OF
BOARD OF DIRECTORS
TENNESSEE VALLEY AUTHORITY
BEFORE THE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE
FEBRUARY 9, 1984

We are pleased to be here today in response to your invitation to present our views on one of the most serious environmental problems facing us and future generations. Acid rain is potentially a slow and quiet danger, that could subtly alter the web of forest and aquatic ecosystems. Scientists believe that emissions created by combustion of fossil fuel are a major culprit in the creation of acid rain. The problem is international and has potential for widespread environmental damage.

Because of our multifaceted mission, TVA has a unique perspective to share with you as you decide what action to take. TVA is a corporate agency and instrumentality of the United States; the Nation's largest producer of electricity; one of the Nation's largest coal consumers; and one of the largest emitters of SO_2, the pollutant which has been most often identified with formation of acid rain. We are also responsible for helping protect the waters and forests in the Tennessee Valley, for stimulating economic development in the Tennessee Valley region, and for promoting the wise use of its natural resources--responsibilities that go far beyond producing power. TVA has over 50 years of experience in reconciling apparently conflicting interests and solving interrelated energy and environmental problems.

As a federally owned producer of electric energy, TVA believes that its role is to serve as a leader in the electric utility industry in seeking solutions to national problems. We have often been successful in combining our special responsibility to pursue a broader public interest with our technical, real-world-of-business perspective and bring them both to bear on public issues such as acid rain. It is in this spirit that we offer our observations.

TVA Position

TVA is not in accord with the program of the President. It represents the opinion of the TVA Board. Simply put, our position on acid rain is that a reduction in acid precursors is essential in eastern North America, and that Federal legislation is necessary to accomplish this. Reductions should be required of all significant emitters of SO_2, both utilities and other industries. These SO_2 reductions should be allocated to the States proportionally to their total SO_2 emissions for the 1980 base year. States should have flexibility in allocating their required emissions reductions.

TVA believes in the principle that the polluter should pay, and we practice what we preach. The costs of further reduction should be borne by the polluters and thus passed on to consumers. Maximum flexibility should be given to emitters to select the most cost-effective way to reduce their emissions. If acid rain legislation is structured in this way, we estimate the increased cost to TVA rate-payers could be about 4-6 percent for our share of a 12-million ton national reduction. We stand willing to do our fair share in any cleanup effort.

Acid Rain Research

Acid rain is too often thought of as a regional problem, confined to the northeastern United States and eastern Canada.

However, we have rainfall in the Tennessee Valley whith is as acidic as that found anywhere in North America. Based on a monitoring program which began in 1971, we know that on an average annual basis our rainfall is in the pH 4.1 to 4.4 range--typical of the values for New England, and we get much more rainfall than New England. The pH of rainfall at monitoring sites remote from our fossil-fired generating plants is similar to that which falls at monitoring stations at the plants themselves. While our data do not show any trend toward increased acidity, comparative data for the eastern United States between 1955 and 1973 do indicate a trend toward decreased levels of pH and increases in the aerial extent of low pH rainwater. These data are of particular concern to us because most of the increase seems to be toward the Southeast.

While we have no direct evidence of a link between acid deposition and impacts to resources in our region, several observations over the last several years could be related to acid deposition. We have found, for example, that after rainfalls the pH levels of some streams are depressed to the extent that aquatic life could be adversely affected. Our initial research indicates that in one particular watershed the acidic nature of the soils appears to be the probable cause of the pH depression. We have also observed fishkills at trout rearing facilities, unusually high incidences of skeletal deformities in smallmouth bass in several reservoirs, and a decline in the range of the native Appalachian brook trout over the last two decades. These observations could be linked to acid rain, although pesticide and herbicide runoff and natural soil acidity are also possible causes for some.

Some possible terrestrial effects also have been observed. We have recently become aware of a problem with increased mortality and decreased vigor of trees in the Valley region that began about 20 years ago. Core samples show a buildup of heavy metals in the trees associated with this condition. The cause of this widespread problem has not been determined. There are scientists, both within TVA and outside, who believe that acid deposition could be a causative factor.

Appendix A gives additional information on these observations and on the TVA acid rain research program.

TVA Cleanup

TVA has just completed the largest air pollution cleanup effort by a single emitter in U.S. history. In the past six years TVA cut its SO_2 emissions by 56 percent, from 2.3 million to 1 million tons per year, and particulate emissions by 100,000 tons or over 90 percent. The total investment so far has been $927 million. The annualized cost is about $346 million in 1984 dollars. This emission reduction program, which brought TVA into compliance with the Clean Air Act, utilized a number of control approaches, including advanced coal washing, installation of scrubbers, and fuel switching to lower sulfur coal. Further emissions reductions have been achieved as a result of increased emphasis on energy conservation. The entire cost, we should stress, was paid by TVA ratepayers, whose electric bills increased about 9 percent as a result of these efforts. Appendix B gives more detail on our cleanup efforts to date and their cost.

We think that additional cleanup of emissions can be accomplished at reasonable cost to our ratepayers. An appendix to this statement (Appendix C) outlines the projected range of costs and the assumptions used to arrive at them. We estimate that TVA rates would have to be increased by an additional 4-6 percent by 1995 if we reduced our emissions by as much as 50 percent below present allowable levels. This reduction would represent TVA's fair share of a 12-million ton reduction from total utility and nonutility 1980 SO_2 emissions in the eastern 31 States. We estimate that our rates would have to be increased by no more than 4.2 percent to achieve our share of a 10-million ton goal if Congress enacted the legislation.

While each utility system's unique characteristics make it difficult to generalize, TVA's recent experience is useful from several perspectives. For one thing, it illustrates the advantage of applying the most flexible methods to achieve emission reductions. This means that in addition to having the flexibility to select the lowest cost emission control methods at particular plants, we could also take into account methods for reducing coal-fired generation on our power system. Our energy conservation efforts are a good example. These efforts are designed to eliminate the need for new capacity and thereby reduce the cost of electricity to the TVA ratepayer. By 1990 we expect our conservation efforts to reduce our generating capacity requirements by 3,000 MW with a saving of 5.7 billion kWh. Generating those 5.7 billion kWhs by coal-fired steam plants would have increased our annual SO_2 emissions by 90,000 tons. Each kWh saved is a cost-effective investment for us, compared to the alternatives of building new capacity, and we get the added benefit of not having to control those additional emissions.

Our experience also suggests that the cost of compliance by other electric systems with any additional emissions reductions required to control acid rain may be overestimated. In evaluating the estimates of the increased cost to consumers of acid rain controls, TVA's own estimates for its system are instructive. The TVA system is in the heart of the high sulfur coalfields and TVA emissions currently are close to the average of all utilities in the 31-State area. Thus, estimates that TVA ratepayers would experience no more than a 6 percent increase for its fair share of a reduction in the 31-State area of 12 million tons should be a useful benchmark. TVA's costs are influenced by the reliance on existing non-SO_2 emitting generating capacity and our plans to complete construction of four additional nuclear reactors by the end of this decade. But, while the rate impacts on utilities which rely on coal for a smaller or larger portion of their generation could be smaller or larger, TVA's annual costs of reducing emissions as indicated in Appendix C should be representative of realistic costs for these levels of reduction.

We further believe that any costs necessary to clean up the air should be borne by those who are causing the problem. The principle that the polluter should pay for cleaning up is sound economics and is built into the basic environmental regulatory framework we have established in this country. Departing from it, as some have advocated for acid rain, would, in our opinion, set an unfortunate precedent. Subsidies for polluters would send the wrong signals to utilities and their consumers about the true cost of generating electricity, and such wrong signals can only lead to more wasteful use of electricity and a higher level of pollution. We would urge the committee to avoid any type of special subsidy for the cleanup effort, as you did in the legislation reported last session.

Technology Research

TVA has done pioneering work in SO_2 emissions control technology since the late 1960s, and our major role in flue gas desulfurization development began in 1972 with the construction of three 10-MW pilot plants at our Shawnee Steam Plant in Paducah, Kentucky. Since then, more than $35 million has been invested by the Environmental Protection Agency, Electric Power Research Institute, the Department of Energy, TVA, and others at this facility. Numerous technology advancements are available today because of this effort. For example, developments in forced oxidation and waste disposal will enable us to retrofit these technologies into the full-scale scrubbers at our Widows Creek units 7 and 8. We are also active in preparing technology assessments and cost estimates for both recovery and throwaway processes. These estimates are quoted throughout the industry.

Today, our efforts are also focused on demonstrating Atmospheric Fluidized Bed Combustion (AFBC) which we think holds the greatest promise for the future of high-sulfur coal. TVA projections indicate that a new AFBC boiler fueled with Illinois-basin, high-sulfur coal will produce electricity at a cost 10 to 20 percent less than a conventional plant with scrubber. Such a plant could achieve greater than 90 percent sulfur removal and would produce less oxides of nitrogen than a conventional plant. This projection is based on our experience with the AFBC 20-MW test facility which we have operated for almost two years.

TVA has taken the lead in a cooperative development with the Electric Power Research Institute, Duke Power, the State of Kentucky, and others in designing and demonstrating a commercial-size plant. Of the $220 million required $30 million is being provided by the Federal treasury. We are now designing the plant and if all goes well, this technology should be commercially available in the 1990s.

TVA is also actively pursuing dry flue gas desulfurization technology (commonly known as spray dryer) on high sulfur coal at the Shawnee Steam Plant. Two pilot plants supplied by different vendors are providing critical data necessary to adopt this technology in the eastern United States. We are considering a larger, commercial scale demonstration of this technology.

Other technologies that need further development or demonstration include double alkali using limestone, limestone injection multiple burner; lower cost recovery systems, retrofittable technologies for existing outdated limestone scrubbers, and combined NO_x/SO_2 removal processes.

TVA is also involved in research to improve our technology for removing sulfur from coal. For example, we are demonstrating at our Paradise Steam Plant high gradient magnetic separation technology which improves Btu recovery and sulfur reduction in the fine coal washing circuit. We are conducting research on oil agglomeration and magnetite recovery processes which recover clean coal from fine coal refuse and extract magnetite from fly ash, respectively.

Additional research is needed to develop some cost-effective chemical coal cleaning technology that may be tailored to remove almost any desired amount of sulfur from coal, especially for those cases where greater than 50- to 60-percent reduction in sulfur is required.

Research and development of this type, along with various synthetic fuel processes, provide hope for the future of the high-sulfur coal industry.

Conclusion

Mr. Chairman and members of the Committee, we recognize that you have been among the most responsible and farsighted in dealing with the acid rain problem and we commend you for it. Any increase in costs arising from a control program will be painful, but these increased costs need to be put into perspective. Compared to the costs which ignoring the acid rain problem may impose, these costs are reasonable. The bill you reported in the last Congress still stands as the high watermark in the overdue effort to control acid rain. We think the American people strongly support taking positive legislative steps to clean up our air and not run the risk of greater damage from acid rain.

The majority of the TVA Board supports legislation now to achieve a 10-12 million-ton reduction in SO_2 over the next decade in a cost-effective manner and without subsidies of any kind, but the Chairman prefers to wait until EPA recommends a level of national SO_2 emissions with the understanding that TVA would meet its fair share of the reductions at that time.

Mr. Chairman, we would be pleased to address any questions you or other members of the Committee may have.

APPENDIX-C

ASSUMPTIONS USED IN DEVELOPING COSTS OF ACID RAIN CONTROL BASED ON TOTAL SO_2 EMISSIONS

1. Utilities will be required to take all the SO_2 reductions for the State.

2. Each utility's share of the SO_2 reductions would be proportioned based on the total utility SO_2 emissions in the State.

3. TVA-required reductions in Tennessee, Alabama, and Kentucky can be taken anywhere on the system regardless of State lines.

4. Compliance will begin in 1995.

5. Each power plant has an economic writeoff period of 30 years. Limestone scrubber retrofits will be written off over the remaining economic writeoff period of each plant. A discount rate of 15 percent is used.

6. Limestone scrubber retrofits are evaluated at a capital cost of $200/kW in 1983 dollars, including interest during construction. A SO_2 removal efficiency of 85 percent is used. No major changes in scrubber costs are considered which could result from a major increase in demand.

7. The assumed price of low-sulfur coal does not include potential additional premiums due to a major increase in demand.

8. Compliance is met by a combination of least emissions dispatching, fuel switching, and limestone scrubbing.

9. No offsets or costs for additional controls for new sources are included.

10. Nuclear generation for each year will not drop below a level corresponding to an overall nuclear capacity factor of 60 percent. Normal hydro generation is assumed for each year.

11. No major unplanned outages at coal-fired plants where limestone scrubbers or lower sulfur coal is used are considered.

12. No transmission constraints which would prohibit or limit least emissions dispatching are included.

13. The minimum impact case is based on low load growth with a high level of conservation (20.9 billion kWh savings in FY 2000).

14. The major impact case is based on no additional nuclear capacity beyond Hartsville unit A 2. The minimum impact case is based on no additional nuclear capacity beyond Bellefonte unit 2.

15. Minimum cost case includes the cost incurred to protect against actual loads being higher than projected minimum.

16. Plants with limestone scrubbers for the maximum and minimum impacts are:

Reduction Goal	Maximum Impact	Minimum Impact
8 million tons	Cumberland (partial scrubbing)	---
10 million tons	Cumberland	---
12 million tons	Cumberland, Paradise unit 3, Gallatin (partial scrubbing)	Cumberland (partial scrubbing)

ATTACHMENT 1

Cost to TVA of Various SO_2 Reductions if Allocation is Based on Total SO_2 Emissions in Each State[a,b]

National Reduction	Maximum Impact[c]			Minimum Impact[c]		
	Reduction in SO_2 Emissions from present stds	Capital Investment	Annual Cost	Reduction in SO_2 Emissions from present stds	Capital Investment	Annua Cost
	(1,000's tons)	($millions)	($millions)	(1,000's tons)	($millions)	($milli
8 million tons	371	100	150	11	0	0
10 million tons	535	520	240	175	0	90
12 million tons	699	875	340	339	300	160

a. All costs in 1983 dollars.

b. Potential Rate Impacts on TVA System - TVA has the potential to achieve significant SO_2 reductions at relatively low cost by replacing coal-fired generation with generation from four nuclear units presently under construction. With projected load forecasts and the nuclear and coal-fired generation available to meet these projected needs, the expected rate impacts in 1995 would be as follows:

8 million ton reduction	0 to 2.6%
10 million ton reduction	2.5 to 4.2%
12 million ton reduction	4.5 to 6.0%

c. TVA's 1980 SO_2 emissions totaled 1.386 million tons compared to a peak emission level of 2.381 million tons in 1976. Under the maximum impact (high load growth scenario) SO_2 emissions would total 1.30 million tons in 1995 with present emission standards. Under the minimum impact (loads remain essentially unchanged from their present levels) in 1995, SO_2 emissions would total 0.94 million tons with present emissions standards.

8/9/83:EAPSS

APPENDIX A

ENVIRONMENTAL EFFECTS IN THE TENNESSEE VALLEY

The Tennessee Valley Authority (TVA) recognizes that acidic deposition can contribute to long-term damage to sensitive ecosystems. It is evident that scientifically assessing acidic deposition impacts is extremely complex, and establishing strict cause-and-effect relationships may not be possible. Nevertheless, TVA believes that acidic deposition is one of several factors involved in documented effects on Tennessee Valley forests, waters, and fish. Although we have no direct evidence of a link between acidic deposition and impacts to the resources in the Tennessee Valley, certain observed conditions have led us to the conclusion that acidic deposition could be a significant threat to the Tennessee Valley's environment.

Forests

o Altered growth patterns and declining productivity of red spruce, shortleaf pine, hemlock, hickory, yellow birch, pitch pine, and Fraser fir in the Great Smoky Mountains National Park.

o Changes in the present mix of tree species.

o Increased susceptibility of some tree species to damage by insects and disease.

o Changes in the availability of essential nutrients and increased availability of toxic metals in the soils.

Water Quality

- o A trend of increasing acidity and decreasing alkalinity in high elevation streams in the Southern Blue Ridge Province.
- o Short-term acidification of surface waters following heavy rains.
- o Acidic conditions in reservoirs in the Southern Blue Ridge Province.

Fisheries

- o Unusually high incidence (up to 28 percent) of spinal deformities in smallmouth bass collected from Chatuge Reservoir in north Georgia and Fontana Reservoir in North Carolina.
- o Mortality of fish in fish hatcheries supplied with water from various streams draining the Great Smoky Mountains National Park following heavy rains.
- o Decline in the range of native Appalachian brook trout in mountain streams of the Southern Blue Ridge Province.

TVA RESEARCH ON ACID DEPOSITION EFFECTS

The objective of TVA's acid deposition research program is to determine (1) what damages are occurring or are likely to occur in the Tennessee Valley region as a result of acid deposition and (2) what can be done to mitigate damages. This research will provide:

1. An assessment of the extent and magnitude of any damages.
2. An understanding of the processes responsible for these damages and a basis for mitigative action.
3. A baseline of information on acid sensitive regions for evaluating the effectiveness of mitigation and control measures.

Current and past efforts of TVA staff have shown that the aquatic and forest resources of the Blue Ridge Province of the Southern Appalachians have the highest potential for adverse impact in the Tennessee Valley. Therefore, TVA's research focuses on an assessment of damage to these resources and detailed investigations of identified problems in this sensitive region.

The following summarizes TVA's current acid deposition research in forestry, water quality, fisheries, and atmospheric processes.

Forestry

Forest Inventory Statistics--Trends in forest productivity are being assessed in the upper Tennessee Valley watersheds. Mortality and growth are being assessed based on productivity statistics from 125 forest plots routinely surveyed between 1960 and 1975.

Impacts of Forest Soils Chemistry on Surface Water Quality--Laboratory studies are being conducted using soil samples from watersheds in the Southern Blue Ridge Province to determine the influence of soils chemistry on the acidification of surface waters.

Impacts of Acid Precipitation on Forest Soils--Existing data are being used to determine the significance of human inputs of acidity, natural internal production of acidity, and the contribution of tree harvesting to nutrient losses from forest soils; and to evaluate present and future adequacy of soil nutrients for sustained forest productivity. The Department of Energy (DOE) is funding this project.

Forest Soils Hydrology--Upper elevation slopes have been instrumented to quantify flow rates through soils during rainfall. The chemistry of soil solutions and stream samples is also being measured.

Nitrogen Deposition on Forested Watersheds--Nitrogen input via wet and dry deposition and output via streamflow at three forested watersheds with potentially different nitrogen loading rates and proximities to coal-fired power plants are being quantified and compared. Impacts of atmospheric nitrogen deposition on nutrient cycling in forested watersheds are being determined. The Electric Power Research Institute (EPRI) is funding this project. This study complements a similar TVA study of sulfur deposition, funded by the U.S. Environmental Protection Agency (EPA), conducted at two of the three watersheds.

Evaluation of Simulated Acid Precipitation Effects on Forest Ecosystems--Foliar leaching rates and plant nutrient content, leaf physiological and morphological responses, decomposition rates in litter and mineral soil, and leaching rates of soil nutrients are being determined using experimental forest microcosms. Microcosms containing trees and acid sensitive soils have been subjected to simulated acid rain treatments of 3.5, 4.0, 4.5, and 5.7 annual average pH for a two-year period. EPRI is cofunding this project.

Terrestrial Impacts of Acidic Deposition on Deciduous Forests in the Tennessee Valley Region - Modeling Input/Output Relationships--Existing data on sulfur flux to and through forest systems, collected as part of the EPA/TVA passthrough program, are being combined with other meteorological, coal analysis, and coal consumption data generated by TVA along with NOAA radiosonde data to develop a predictive model. The model will relate atmospheric acidic loading and deposition to nutrient cycling in forest ecosystems and will project impacts on forest productivity. DOE is funding this project.

Aluminum Biogeochemistry of Forested Watersheds--The major environmental parameters controlling the release, transport, and toxicity of aqueous aluminum in the natural environment will be identified and quantified, and the interactions between aluminum biogeochemistry and acidic deposition will be analyzed at a watershed in east Tennessee. This project is funded by EPRI.

Water Quality

Trends in Water Quality of Streams and Reservoirs--Water quality surveys of streams and reservoirs in the potentially acid sensitive regions of the Tennessee Valley are being conducted. This long-term program will monitor trends in water quality for future assessment of the effectiveness of acidic deposition controls. EPA is cofunding this project.

Assessment of Recent Trends--Statistical techniques are being applied to previously collected water quality data to assess recent trends in acidification of surface waters.

Reservoir Water Quality and Sources of Acidity--Reservoir conditions that affect pH and trace metal concentrations of concern to fisheries are being evaluated by periodic sampling of selected reservoirs. The relative contributions of various sources of acidity and trace metals to documented acidic conditions and fisheries concerns are being determined.

Fisheries

Response of Smallmouth Bass--The response of smallmouth bass to known transient water quality conditions (pH and aluminum) resulting from snow melt or storm runoff is being evaluated. This project is being conducted with EPA funds.

Skeletal Deformities in Smallmouth Bass in High Elevation Reservoirs--The smallmouth bass physiology, toxic metals and pesticides burdens, and water chemistry of high elevation reservoirs are being investigated to determine the cause and extent of the skeletal deformity problem.

Atmospheric Processes

Atmospheric Dispersion--Photochemical reaction chamber experiments, utilizing flue gases from the operating power plant and surrogate mixtures, are being conducted to simulate production of sulfate and nitrate aerosols and ozone under varying rural and urban atmospheric conditions. Results are being used in developing predictive models for assessing the contribution of existing or proposed TVA coal-fired power plants to local and regional air quality, and for developing effective control strategies.

Air Quality Modeling Technology Research--Air quality models for estimating the local, regional, and interregional air quality impacts of proposed and existing air-pollutant-emitting facilities are being developed and modified. Impacts being investigated include effects caused by the production and long-range transport of acidic pollutants.

Deposition Monitoring--Wet/dry collectors are being used to monitor the long-term rates of atmospheric deposition. Six monitors are operated in the vicinities of coal-fired power plants and three monitors are sited in remote areas. Samples are collected biweekly and are analyzed for 14 parameters including pH, sulfate, nitrate, and weak and strong acidity.

APPENDIX-B

TVA COMPLIANCE WITH THE CLEAN AIR ACT

INTRODUCTION

TVA is now in compliance with the consent decrees under the Clean Air Act. This has been a major achievement for TVA and has significantly improved the Valley's air quality.

Consent Decree Air Quality Control Requirements

Air quality control requirements under the consent decrees involved medium and low-sulfur coal, coal washing, SO_2 scrubbing, precipitators, and baghouses. New stacks were added at two facilities, Colbert and Johnsonville, to ensure that consent decree SO_2 emission standards maintain compliance with all ambient air quality standards at the plants. Prior to the consent decrees, only precipitators, new stacks, and one SO_2 scrubber had been added at the TVA steam plants as air quality control measures.

Table 1 outlines all air quality control measures at the 12 TVA steam plants before and under the consent decrees.

Consent Decree Costs

Air pollution control costs are expressed in terms of the capital expenditures that are involved as well as annual costs. Annual costs involve amortization of the capital expenditure along with operation and maintenance costs. The annual costs are of most interest since they can be related directly to electric rates. Prior to the consent decrees, TVA's air pollution control capital costs were $358 million for the 12 coal-fired steam plants. Consent decree capital costs were $927 million for a total of $1,285 million.

Annual costs for projects before the consent decrees were $43 million, and consent decree annual costu are $346 million for a total annual cost of $389 million (Table 2). The $346 million consent decree annual costs represent a 9 percent increase in electric rates.

Air Quality Results from Consent Decrees

The consent decree actions have resulted in improved air quality both in terms of emission reductions and improved ambient air quality. TVA steam plant system SO_2 emissions are given in Table 3 and show significant reductions under the consent decrees. Pre-consent decree SO_2 emissions were about 2 million tons of SO_2 per year. Under the consent decrees these emissions were reduced to about 1 million tons per year (Table 3). Plant-by-plant SO_2 and particulate emissions before and after most of the consent decree projects were completed are given in Tables 4 and 5. NO_x emissions are given in Table 6. Ambient SO_2 and particulate information are given in Tables 7 and 8.

Comparison of TVA and National Emissions

Now that the consent decree projects are completed, TVA SO_2, particulate, and NO_x emissions are expected to be about 1 million, .01 million, and 0.5 million tons per year, respectively (Tables 4 through 6). Total national emissions of these three pollutants are 26, 9, and 23 million tons per year for SO_2, particulates, and NO_x (Table 9). These data show the relationship between TVA and the rest of the utility industry to total national emissions of these three air pollutants.

Table 1

SO_2 and Particulate Compliance Methods

TVA Steam Plants

Plant	Compliance Methods Prior to Consent Decree	Consent Decree
Allen	Precipitators	Medium sulfur coal
Bull Run	Precipitators	
Colbert	Precipitators	Medium sulfur coal, New Stack
Cumberland	Precipitators	Precipitators, coal washing
Gallatin	Precipitators	Precipitators, Medium sulfur coal
John Sevier	Precipitators	
Johnsonville	Precipitators	Precipitator upgrade, Medium sulfur coal, New stack
Kingston	Precipitators, New Stacks	Low sulfur coal
Paradise	Precipitators	Precipitator, coal washing, SO_2 Scrubbing
Shawnee	Precipitators, New Stacks	Baghouses, Low sulfur coal
Watts Bar	Precipitators	Medium sulfur coal
Widows Creek	Precipitators, New Stack, SO_2 Scrubbing	Low sulfur coal, SO_2 Scrubbing

Table 2

Air Pollution Control Costs and Consent Decree Completion Dates

TVA Steam Plants

Plant	Annual Costs (millions of '82 Dollars) Non-Consent Decree	Consent Decree	Total	Consent Decree Completion Dates
Allen	2	4	6	5/ 4/79
Bull Run	5		5	
Colbert	5	6	11	8/ 1/79
Cumberland	1	56	57	10/19/82
Gallatin	2	25	27	6/15/79
John Sevier	2		2	
Johnsonville	4	33	37	7/ 2/82
Kingston	10	18	28	6/29/79
Paradise		103	103	12/14/83
Shawnee	5	55	60	10/ 1/81
Watts Bar		–	–	7/ 2/81
Widows Creek	7	46	53	12/17/81
TOTALS	43	346	389	

Table 3

Total Annual SO_2 Emissions

TVA Steam Plants

Fiscal Year	Total SO_2 Emissions (Millions of tons)
1977	2.4
1978	1.9
1979	1.7
1980	1.6
1981	1.6
1982	1.2
1983	1.0

Table 4

SO_2 Emissions Information

TVA Steam Plants

Plant	SO_2 Emissions (1000 tons/year) FY 1977	SO_2 Emissions (1000 tons/year) After Consent Decree Compliance*	Consent Decree SO_2 Emission Standard (lb $SO_2/10^6$ Btu)
Allen	113	69	4.0
Bull Run	109	38	4.0
Colbert	229	135	4.0
Cumberland	363	216	5.0
Gallatin	155	134	5.0
John Sevier	96	75	4.0
Johnsonville	213	114	3.4
Kingston	178	94	2.8
Paradise	394	161	3.1
Shawnee	278	43	1.2
Watts Bar	34	18	4.0
Widows Creek	189	44	1.2
TOTALS	2,351	1,141	

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*Projection based on FY 1981 coal receipts

Table 5

Particulate Emissions Information

TVA Steam Plants

Plant	Particulate Emissions (1,000 tons/year) FY 1977	After Consent Decree Compliance*	Consent Decree Particulate Emission Standard (lb. particulates/10^6 Btu)
Allen	1	.8	.10
Bull Run	38	.1	.11
Colbert	3	2.5	.12
Cumberland	6	3.3	.10
Gallatin	28	.1	.10
John Sevier	1	.4	.11
Johnsonville	2	.8	.10
Kingston	1	.5	.10
Paradise	13	.9	.11
Shawnee	9	.4	.11
Watts Bar	2	.6	.14
Widows Creek	60	1.2	.12
TOTALS	164	11.6	

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*Projection based on FY 1981 coal burn rates

Table 6

NO_x Emissions Information

TVA Steam Plants

Plant	FY 1981 NO_x Emissions (1,000 tons/year)
Allen	43
Bull Run	21
Colbert	26
Cumberland	40
Gallatin	23
John Sevier	17
Johnsonville	29
Kingston	41
Paradise	139
Shawnee	29
Watts Bar	4
Widows Creek	31
TOTAL	443

Table 7

Highest 24-hour Ambient SO_2 Concentration

TVA Steam Plants

Plant	Highest 24-hour Average SO_2 Concentration (ppm)	
	1977	1981
Allen	.07	.16
Bull Run	.06	.03
Colbert	.17	.10
Cumberland	.10	.10
Gallatin	.18	.13
John Sevier	.10	.11
Johnsonville	.23	.13
Kingston	.10	.08
Paradise	.18	.18
Shawnee	.27	.09
Watts Bar	.13	.11
Widows Creek	.35	.18

Table 8

Highest 24-hour Suspended Particulate Concentrations

TVA Steam Plants

Plant	Highest 24-hour Suspended Particulate Conc. ($\mu g/m^3$) 1977	1981
Allen	360	149
Bull Run	153	99
Colbert	187	125
Cumberland	184	91
Gallatin	222	93
John Sevier	103	108
Johnsonville	510	384
Kingston	173	101
Paradise	598	125
Shawnee	186	100
Watts Bar	90	89
Widows Creek	266	196

Table 9

Calculated National Air Pollution Emissions

1980

Source	Air Pollution Emissions (10^6 tons/year) Particulates	SO_2	NO_x
Utilities	1	18	7
Industrial	4	7	4
Transportation	2	1	10
Other	2	-	2
TOTAL	9	26	23

COST OF COMPLIANCE WITH AIR QUALITY CONSENT DECREE REQUIREMENTS TVA COAL-FIRED GENERATING PLANTS

Discussion

In August 1981, the capital cost for implementing the compliance program covered by the consent decree was estimated to be $724 million. We also estimated that by 1983, when the program was scheduled to be completed, annual costs would be $334 million in 1982 dollars.

In the two years since this estimate was made, a number of changes have occurred which have increased the capital cost estimate to $927 million, or an increase of $203 million above the 1981 estimate. A plant-by-plant summary of the costs is given in the attached table 1. The major reasons for this increase are as follows:

1. In FY 1982, TVA's accounting practices were modified for capitalizing an allowance for funds used during construction for projects of this type. This change resulted in an increase of $73 million in the capital cost of projects which were not completed before FY 1982. Over half of these charges ($46 million) are against the Paradise scrubber project.

2. Our 1981 estimates only included costs for temporary refuse and sludge disposal facilities at Widows Creek. Since that time, more permanent disposal arrangements have been designed or are being installed. Sludge disposal provisions at this plant have resulted in an increase of $22 million.

3. In addition to the cost increases identified in items (1) and (2) above, the major differences in capital costs for these projects are as follows:

    a. Paradise Scrubbers--The inability of Envirotech Corporation to fulfill the terms of its contract resulted in a takeover of the project by TVA. This change in project management caused a major disruption which increased the time required to complete the project, thus resulting in an increase of costs. Also this project had several scope additions, such as ballmill and maintenance building, handling and maintenance equipment, and transformer rectifier. The total cost increase, including associated overheads, is about $47 million.

    b. Cumberland Precipitators--The cost of additional construction work which required gas duct system, erection of precipitators, and reinforcement of stack breaching and associated overheads is estimated to be $9 million. The extended construction schedule, fire protection, health and safety items, and work requiring a plant outage resulted in an additional increase of $3 million.

c. Shawnee Baghouses--The baghouse has to be rebagged and respringed due to unacceptable material used for the original bags. The total cost for this and additional scope of reversed air modulating and cleaning the system is $9 million.

d. Paradise Coal Washing--The cost increase for this project is for several scope additions. These additions are constructing a coal fines refuse disposal area, enlarging the reclaimed hopper, and relocating county roads and coal yard handling facilities. The cost for this increase and associated overheads is about $27 million.

e. Paradise Precipitators--Precipitator transformer rectifier (TR) sets were not operating properly which resulted in an operational failure. The TR set failures present safety and fire hazards, and the sets are unreliable during operation. Their replacement cost is approximately $5 million. Scope additions for hopper heaters, railroad modifications, and extended construction schedule resulted in an increase of $3 million with a total project cost increase of $8 million.

f. Widows Creek Scrubbers, Unit 7--The increased scope of work in the scrubber contract, additional cost for steam piping, framing modifications, and hoisting equipment, along with associated overheads, resulted in an increase of $8 million.

g. Gallatin Precipitators--Additional scope for hopper heaters and extended construction schedule resulted in an increase of $6 million.

As indicated in table 1, some of the above cost increases were offset by a combined saving of $9 million on Cumberland coal washing and Johnsonville stacks and precipitator upgrade projects.

The attached table 2 shows updated estimates of the annual cost associated with the consent decree compliance program, including amortization of investment, premium for low-sulfur coal, coal-washing costs, and operating and maintenance costs for pollution control equipment. In 1981 we had estimated our annual costs would be $334 million (1982 dollars) upon completion of the program. We now estimate these annual costs at $346 million (1984 dollars). The increases in annual costs resulting from higher capital costs and two additional years of inflation are partially offset by cost reductions due to lower coal-fired generation on the system.

The revised FY 1984 annual operating and maintenance cost and coal premium estimates are based on FY 1984 plant operating levels projected by the Division of Power System Operations during April 1983. At these operating levels, the power system is projected to burn about 29 million tons of coal. The earlier cost estimate for FY 1983 operation was based on an annual coal burn rate of approximately 33 million tons. Thus, should the total coal burn for FY 1984 be higher or lower, the actual costs could vary from this value using a nominal coal burn. Other assumptions for operating and maintenance costs are (including unit coal premiums) similar to those which formed the basis for our earlier estimates of the annual costs of compliance.

For your information, we have also updated the total capital cost estimates of TVA's total air compliance program. With capitalized interest during construction included for FY 1982 and later, the total capital cost estimate will be $1.285 billion. This program includes the consent decree projects, the projects implemented prior to the consent decree, and one project (the Colbert Steam Plant stack) which was implemented after the consent decree.

The attached table 3 shows that, by 1984, TVA will have invested approximately $1.3 billion in air pollution control equipment at its 12 coal-fired plants. The annual cost of amortizing this investment and of operating and maintaining the equipment will be about $225 million for FY 1984. In addition, TVA must pay a premium price for the lower sulfur coal being burned at its plants. It is estimated that this premium adds about $164 million (1984 dollars) for FY 1984 to the cost of coal being burned at these plants. This includes the cost of washing the coal burned at Paradise and Cumberland. Thus, the total annual cost of air pollution control at TVA's plants is estimated to be about $389 million (1984 dollars) as shown in table 4 (attached). The premium price for the low-sulfur coal being burned and estimated operating and maintenance costs would vary, depending upon the operating levels of coal-fired plants. For example, a 10-percent increase in coal burn rate would raise the total FY 1984 annual coal premium cost by about $20 million (1984 dollars).

The revised estimates do not indicate any change from earlier estimates of increased revenue requirements because of the air quality compliance program. In FY 1984, when TVA's pollution control program will be completed, these costs would result in an increase of about 9.7 percent in TVA's total revenue requirements. However, as indicated above, in subsequent years this percentage will vary, depending upon the use of TVA's coal-fired generating system and supply of load demand from nuclear plants.

Table 1

AIR QUALITY COMPLIANCE PROGRAM - CAPITAL COSTS
CONSENT DECREE PROJECTS ONLY
(MILLIONS OF DOLLARS)

Plant	Type of Equipment	August 1981 Estimates	November 1983 Estimates
	Sulfur Dioxide		
Cumberland	Coal washing	$ 53	$ 52
Johnsonville	Stacks and precipitators upgrade	69	67
Paradise	Coal washing	115	145
	Scrubbers units 1 and 2	151[a]	244[a]
Shawnee	Baghouses	76	85
Widows Creek	Scrubbers unit 7	48	56
	Sludge disposal	-	25
Total (SO_2 only)		512	674
	Particulates		
Cumberland	Precipitators	120[a]	144[a]
	Provision for scrubbers	19	19
Gallatin	Precipitators	43	52
Paradise	Precipitators unit 3	30	38
Total (particulates only)		212	253
Grand Total		$724	$927

a. Does not include the cost of balanced draft conversion.

Table 2

AIR QUALITY COMPLIANCE PROGRAM - ESTIMATED ANNUAL COSTS
CONSENT DECREE PROJECTS ONLY
(MILLIONS OF DOLLARS)

Plant	Compliance Method	August 1981 Estimates For FY 1983[a]	November 1983 Estimates For FY 1984[b]
	Sulfur Dioxide		
Allen	Medium-sulfur coal	$ 5	$ 4
Colbert	Medium-sulfur coal	8	6
Cumberland	Coal washing	30	34
Gallatin	Medium-sulfur coal	16	18
Johnsonville	Lower sulfur coal and precipitator upgrade	50	33
Kingston	Low-sulfur coal	12	18
Paradise	Coal washing and scrubber units 1 and 2	83	97
Shawnee	Low-sulfur coal	43	41
	Baghouses	13	14
Watts Bar	Medium-sulfur coal	2	-
Widows Creek	Low-sulfur coal (units 1-6); scrubbers and medium-sulfur coal (units 7 and 8)	42	46
Total (SO_2 only)		$304	$311
	Particulates		
Cumberland	Electrostatic precipitators	$ 19	$ 22
Gallatin	Electrostatic precipitators	7	7
Paradise unit 3	Electrostatic precipitators	4	6
Total (particulates only)		$ 30	$ 35
Grand Total		$334	$346

a. 1982 dollars based on 33 million tons of coal burned.
b. 1984 dollars based on 29 million tons of coal burned.

Table 3

AIR POLLUTION CONTROL PROGRAM - CAPITAL COSTS
TVA COAL-FIRED PLANTS
(Millions of Dollars)

Plant	Type of Equipment	August 1981 Estimates	November 1982 Estimates
Allen	Precipitators	$ 10	$ 10
Bull Run	Precipitators	33	33
Colbert	Precipitators	22	22
	Stacks and duct	15	15
	Total Colbert	37	37
Cumberland	Coal-washing facility	53	52
	Stacks and precipitators	133[a]	157[a]
	Scrubbers (cancelled)	19	19
	Total Cumberland	205	228
Gallatin	Precipitators	49	58
John Sevier	Precipitators	12	12
Johnsonville	Precipitators	27	27
	Stacks and precipitators upgrade	69	67
	Total Johnsonville	96	94
Kingston	Precipitators and stacks	71	71
Paradise	Coal-washing facility	115	145
	Scrubbers units 1 and 2	151[a]	244[a]
	Precipitators	37	45
	Total Paradise	303	434
Shawnee	Precipitators	9	9
	Baghouses	76	85
	Tall stacks	26	26
	Total Shawnee	111	120
Watts Bar	Precipitators	2	2
Widows Creek	Precipitators and stacks	55	55
	Scrubbers	98	106
	Sludge disposal	-	25
	Total Widows Creek	153	186
Grand Total		$1,082	$1,285

a. Does not include the cost of balanced draft conversion.

Table 4

AIR POLLUTION CONTROL PROGRAM - ESTIMATED ANNUAL COSTS
TVA COAL-FIRED PLANTS
(Millions of Dollars)

Plant	Compliance Method	August 1981 Estimates For FY 1983[a]	November 1983 Estimates For FY 1984
Allen	Precipitators, medium-sulfur coal	$ 6	$ 6
Bull Run	Precipitators, medium-sulfur coal	4	5
Colbert	Precipitators, stacks and duct, medium-sulfur coal	14	11
Cumberland	Coal washing, precipitators	50	57
Gallatin	Precipitators, medium-sulfur coal	24	27
John Sevier	Precipitators, medium-sulfur coal	2	2
Johnsonville	Precipitators, stacks, lower sulfur coal	54	37
Kingston	Precipitators, stacks, low-sulfur coal	22	28
Paradise	Coal washing, scrubbers units 1 and 2, precipitators unit 3	88	103
Shawnee	Precipitators, baghouses, tall stacks, low-sulfur coal	61	60
Watts Bar	Precipitators, medium-sulfur coal	2	-
Widows Creek	Precipitators, stacks, low-sulfur coal (units 1-6); scrubbers and medium-sulfur coal (units 7 and 8)	49	53
Total		$376	$389

a. 1982 dollars based on 33 million tons of coal burned.
b. 1984 dollars based on 29 million tons of coal burned.

SPECIAL REPORT

Sports Illustrated
April 23, 1984

A Rain Of Death On The Striper?

Pulses of acid rain arriving in the stripers' spring spawning season may be the doom of this legendary inshore game and table fish

by ROBERT H. BOYLE

Consider the plight of the striped bass, the legendary game and food fish of the Atlantic Coast. Late last month, the House Subcommittee on Fisheries and Wildlife Conservation and the Environment held a hearing on a bill, H.R. 4844, introduced by Representative Claudine Schneider (R., R.I.). Mrs. Schneider's bill calls for a three-year moratorium on possession of striped bass by sports and commercial fishermen anywhere on the East Coast, including spawning streams. She introduced it because mature striped bass are disappearing at an alarming rate. Worse, there aren't very many young fish joining the ranks. Most notably, the important spawning rivers tributary to Chesapeake Bay haven't produced a "dominant year class," a super brood of young, since 1970. Unless the trend is reversed, the striped bass in Chesapeake Bay will go the way of the passenger pigeon.

Since 1973, the sports and commercial catch of striped bass on the East Coast has declined by 90%, and this catastrophic slump has cost coastal counties from North Carolina to Maine a potential $220 million annually and 7,000 jobs. Even with striped bass in short supply, in 1980 the fish still generated $90 million in direct expenditures, $200 million in related economic output and 5,600 jobs, plus a heck of a lot of recreation, and superb eating.

The very idea that the striped bass is threatened is cause for alarm. For more than three-quarters of a million East Coast anglers, the striped bass *is the* glamour game fish, and for many commercial fishermen, the striped bass is *the* money fish, the difference between going broke and making a living. Ever since the days of Captain John Smith, who wrote that he had seen such multitudes of bass in the area "that one mighte go over their backs drishod," the fish has been esteemed. In 1639, the Massachusetts Bay Colony passed the first conservation law in the New World by prohibiting the use of striped bass as fertilizer, and in 1670 the Plymouth Colony used the profits from the sale of striped bass, herring and mackerel to found the first public school on this continent. In the 1870s, wealthy New Yorkers established striped bass fishing clubs on the Rhode Island and Massachusetts

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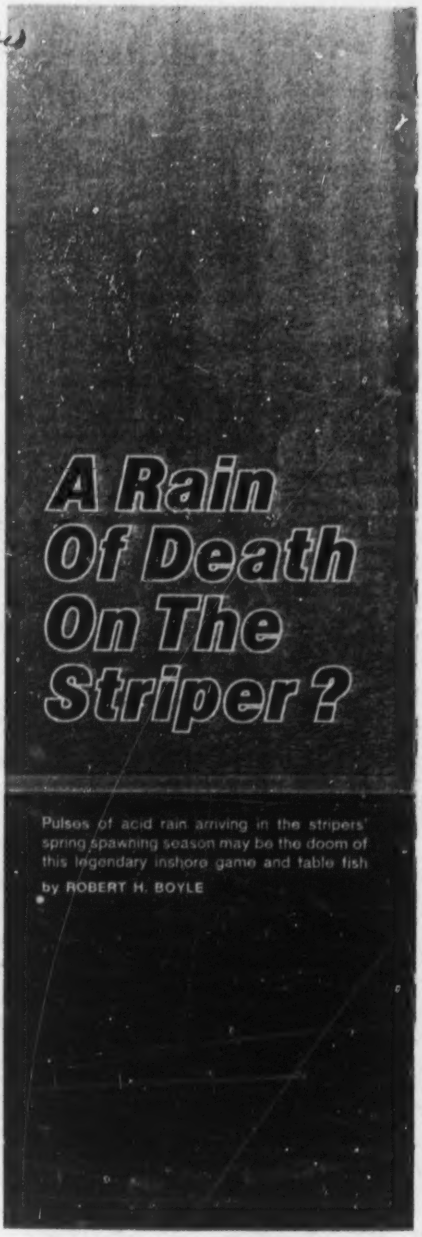
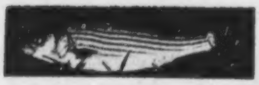


Jim Price, a fifth-generation Chesapeake Bay fisherman, sits out a shower that could wreak further havoc.



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coasts, and Robert Barnwell Roosevelt, Teddy's uncle, declared that surfcasting for striped bass was "the noblest sport of the salt water." In the years after World War II, angling for striped bass along the Atlantic Coast became increasingly pop-

As Janicki monitors a spawning stream, his pH meter displays a high level of acidity.

ular, and in 1970, anglers caught 73.3 million pounds of the fish while a decade later they landed only 1.3 million pounds.

Like the Atlantic salmon, the striped bass is an anadromous fish, *i.e.*, it lives in salt water but spawns in freshwater rivers, notably the Hudson and the numerous larger tributaries of Chesapeake Bay, such as the Potomac, Patuxent, Choptank, Nanticoke and Chester. As recently as 10 years ago, the Chesapeake was known as "the queen of estuaries." There was no king. Estuaries are the most productive nurseries of fish and shellfish on earth, and the Chesapeake was the most bountiful estuary in the world. Historically, the Chesapeake supplied more than 80% of the striped bass that migrated along the East Coast. That fishery has gone into precipitous decline since 1974.

In a statement to the House, Schneider blamed fishing pressure and chemical contamination for the collapse of the Chesapeake bass stocks, and she asked for the three-year moratorium because "this is the minimum amount of time that scientific experts deem necessary for any recovery of the striped bass population to begin." She added, "If the annual survey of reproductive success in the Chesapeake Bay should remain at a critical level, the moratorium could be extended for an additional two years."

Sad to say, it is SPORTS ILLUSTRATED's opinion that the moratorium could be extended to 10 years with little or no improvement. This magazine has uncovered sufficient preliminary data and circumstantial evidence to offer the hypothesis that acid rain is significantly responsible for the decline of striped bass reproductive success, and benign neglect is no solution at all if that is the case.

Moreover, it's foolish to look at the striped bass in isolation, as Congress is now doing. Available data and evidence also suggest that acid rain may have had an adverse effect on six other commercially valuable species that spawn in tributaries of the Chesapeake in Maryland: white perch, yellow perch, American shad, hickory shad, alewife and blueback herring. As with the striped bass, populations of these species have diminished dramatically over the past 10 years. This decline began in some river systems as early as the 1960s, as an apparent consequence of the poor survival of eggs and larval fish—what biologists call "recruitment failure."

Schneider proposed a bass moratorium.

Additional data and evidence gathered by this magazine also indicate that some or all of the affected species in the Chesapeake may be undergoing recruitment failure elsewhere on the Atlantic Coast. Alarmingly, the Annapolis River in Nova Scotia has not had *any* successful reproduction of striped bass since 1972. Sexually mature fish, which are getting older and larger in size but fewer in number, enter the river to spawn in spring, and though the females lay millions of eggs, the fertilized eggs die off in the river water, which is subjected to acid pulses—stong, sudden doses of acidic water from storms or runoffs. In five years of studying striped bass spawning in the Annapolis, Brian Jessop of Canada's Department of Fisheries and Oceans was not able to collect any larval fish. He does know of another researcher who was able to collect some fish during that period—two.

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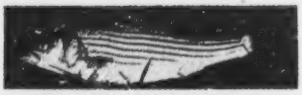

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As any aquarium hobbyist knows, water that is too acidic can kill off fish, especially in their younger stages when they are ultrasensitive. Acidity is measured on the pH scale, which runs from acidic at the low end to alkaline at the high. Every value below 7, the neutral point, is increasingly acidic. The pH scale is logarithmic, so that pH 4.6 is 10 times more acidic than pH 5.6, and pH 3.6 is 100 times more acidic than pH 4.6.

Ordinarily, rain has a pH of 5.6—because it combines with carbon dioxide in the atmosphere to form weak carbonic acid—but this can be greatly depressed by sulfur and nitrogen oxides emitted by coal-burning power plants, smelters, boilers, vehicles and other sources of combustion. In the atmosphere, sulfur and nitrogen oxides can react to moisture and be transformed into sulfuric and nitric acids. These are strong mineral acids that intensify the acidity of rain, and when they fall to earth they can have a devastating impact on land areas and bodies of water that have little natural capacity to buffer themselves. For example, a watershed containing readily available calcium, magnesium or carbonates weathered from limestone can readily buffer acid in much the same way that an Alka-Seltzer tablet will neutralize an upset stomach.

Decades of incoming strong acids have depleted the buffering capacity of some bodies of water and soils; they have run out of Alka-Seltzer, so to speak. This has happened in the Adirondack Mountains in New York, where more than 200 lakes have lost their fish life because of acidification (SI, Sept. 21, 1981). Similarly, the coastal-plain soils in Maryland have scant buffering capacity. Since 1971, Dr. David L. Correll of the Smithsonian Institution and a team of scientists have been investigating the Rhode River watershed, near Edgewater, Md. In a paper delivered in 1982 and published this past February in a book entitled *Geological Aspects of Acid Deposition*, he reports that the coastal plain is "very vulnerable to acid rain." Correll notes that over a seven-year period (1972-78) the mean spring pH of the larger streams in the Rhode watershed dropped from 6.3 to 5.8. Asked his opinion of SI's hypothesis concerning acid rain and its effect on spawning in tributaries of the bay, Correll said, "I've been saying the same thing. I think it's a serious concern that people should be working on." Correll says that striped bass, which used to spawn in the Rhode River system, no longer do so, and that yellow perch "have become extinct" in the watershed. This spring he is monitoring fish spawning and pH levels.

The precipitation (rain, snow, even fog) that falls on Maryland is very acid, as acid as any in the world. Its pH ranges from 4.45 to 3.5; that is 15 to 110 times more acid than normal. A rainstorm in Baltimore three years ago had a pH of 2.9, more than 700 times more acid than normal. When a heavy rain hits this flat coastal plain, it's like throwing a bucket of water on a rubber sheet. What had been up in the sky a few hours before collects in the streams, and the streams can suffer sudden acid pulses. If the pH of a stream isn't being monitored daily, no one will notice the pulse. In a matter of hours, or a day, or two days, the pH can rebound to 7 or more, and the only wit-

continued

Uphoff (foreground) leads trawling expeditions for bass fry: He says that three of the past four years have been "disasters."

continued

nesses to the destructive pulses are the larval fish that have been killed.

According to Dr. Serge Doroshov, who worked on the acclimatization of striped bass in Russia before he defected in 1975—he has taught animal science at the University of California at Davis since 1977—striped bass larvae have difficulty tolerating pH levels below 7. "Mortalities are higher in water with a low pH," he says. "I haven't seen the data [SI has for certain rivers], but with those pH levels I would speculate that striped bass larvae wouldn't survive. The larvae do best in water with a pH of 7.5 to 8.5. At Davis we raise them in water close to pH 8." Moreover, Doroshov adds, striped bass larvae are extremely sensitive to a sharp change of pH even within the favorable pH range. He cites two instances where a sudden change of pH by 0.8 to 1.0 caused 100% mortality.

Boone finds no young shad in the upper bay, few bass.

Last year, the Power Plant Siting Program of the Maryland Department of Natural Resources (DNR) monitored the pH of the headwaters of 23 coastal streams feeding into the Chesapeake. The study was designed by Dr. Tony Janicki of Martin Marietta Environmental Systems of Columbia, Md. and Michael L. Bowman of the DNR. One of the criteria used by Janicki—whose doctoral thesis stemmed from his studier of acid-affected aquatic systems—was that the streams had historically supported spawning runs of white perch, yellow perch, American shad, hickory shad, alewives or blueback herring. These species tend to spawn farther up freshwater systems than do striped bass. Monitoring took place in March and April, and the streams were sampled weekly, not daily. In those two months all 23 streams experienced acid pulses, each dropping to pH 5.8 at least once. The pH of 14 of the streams fell at least once to 5.5, and six of the streams suffered slumps to a pH between 4.9 and 4.5.

Acid rain can mobilize aluminum and other metals toxic to fish—in other words, draw these metals from the soil into the water. A level of only .02 parts per million of dissolved aluminum in stream water is considered to be lethal to many larval fish. The Maryland DNR study revealed that dissolved aluminum levels in some Maryland streams were so high, up to 2.00 to 3.00 ppm on occasion—100 to 150 times the lethal dose—that authorities in the field have strongly questioned the method of aluminum analysis. That research will be extended this spring.

Jay O'Dell, the DNR biologist in charge of migratory fish, helped Janicki pick the streams. O'Dell has walked them all for years, and he says, "I've noticed a decline in spawning runs in some streams in the last 14 years. There's no doubt about it. The river herring [alewife and blueback] runs are gone, or there are reduced populations. The same for yellow perch. Runs are gone that were heavy in the 1970s. The run of yellow perch [in the Rhode River Watershed] is gone, and so are two runs at the head of the Magothy River. Since 1978, yellow perch no longer spawn at all in some freshwater streams. The die-off seems to come in the egg and larval stages. White perch appear to be following the same trend. There are no obvious physical changes, no new pollution. I used to think it was PCBs or chlorine, but now, from what I know, I believe [the cause is] acid rain."

Since 1980, DNR biologist Jim Uphoff has conducted a trawl survey for larval striped bass in the Choptank, a river on the Chesapeake's Eastern Shore. Among other functions, the survey gives the state an early estimate of spawning success. Jim Price, a charter-boat captain in Oxford, Md., is usually out on the Choptank at the same time Uphoff is, catching mature striped bass for research purposes. Price's family has spent 100 years fishing the Choptank, and he's sick at heart at what he has seen. "Back in the '60s and early '70s, the Choptank was full of striped bass," Price says. "In the fall, you could run through 10 to 15 miles of breaking fish. Now we've got practically nothing." In November, Price petitioned the DNR to have striped bass declared a threatened species and thereby accorded protection. The striper happens to be Maryland's official state fish and is on its great seal.

The story that Price and Uphoff tell of striper spawning in the Choptank is the same. Reproduction in the springs of 1980 and 1981 was, in Uphoff's words, "a disaster." In both years, trawls showed that striped bass had reached the larval stage, but after several days of heavy rain they disappeared and presumably died. No pH measurements were taken. In 1982, the Choptank yielded a good crop of striped bass. "It was a fairly dry spring," says Price. Uphoff adds, "The flow stabilized when the eggs hatched, and the fish survived." There were heavy rains again last spring, and striped bass production was nil. "Originally I was the ultimate skeptic about acid deposition in the Chesapeake system," says Uphoff, "but I'm far from that now."

Acid rain may also be affecting striped bass spawning in North Carolina. Last spring, Dr William W. Hassler, at North Carolina State, wanted to collect living striped bass eggs from the Roanoke River—which along with the Hudson and Chesapeake Bay has been traditionally thought of as a prime striper spawning ground—for feeding experiments. He found only 35% of them viable.

Runs of American shad also are down in North Carolina, and are way, way

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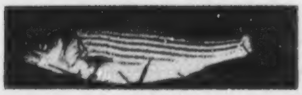

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down in Chesapeake Bay. In 1970 the Chesapeake shad catch was five million pounds, but by 1980 it had declined more than 80% and Maryland imposed a ban on shad fishing.

The ban remains in effect, yet there is no sign that the fish are making a comeback. Maryland DNR biologist Joe Boone, who in summer conducts a survey of the bay for young-of-the-year fish to obtain an annual productivity index for different species, says, "Our annual survey has failed to collect a single young shad in the vast nursery area of the upper Chesapeake Bay for 10 consecutive years." According to bioassay tests done by the Pennsylvania Fish Commission, at about pH 5.5 half the shad eggs became nonviable, and many of the larvae that hatched from the surviving eggs were crippled. At pH 5.2, only 32% of the eggs hatched, and *all* the surviving larvae were "severely crippled."

Since the 1960s, catches of alewives and bluebacks have slumped in Chesapeake Bay. In 1969, the Virginia catch was 30,446,000 pounds. A decade later the catch was down to 1,688,000. Trawling by foreign offshore fishing fleets in the late 1960s and early '70s has been blamed. So has Hurricane Agnes, which struck the Chesapeake in June 1972 and flushed juvenile herring from their prime nurseries. But Joe Boone's index figures show that the Choptank hasn't had decent reproduction of bluebacks since 1958, and Jim Price says, "The trouble with the herring started back in the early '60s. We used to see millions of them spawning in the Choptank, but we were getting no reproduction to speak of. I told the state back then, and all I got from the scientists was that everything is a cycle and all that ——. No one has ever proved a cycle to me. It was a failure of reproduction."

The same goes for yellow perch and white perch in many bay tributaries. Of the Choptank Price says, "I can't find hardly enough white perch to make it pay." Looking over the whole situation, Boone says, "Whatever is controlling the recruitment failure of anadromous fishes is up in the freshwater rivers and *not* in the bay, and recruitment failure has been fairly widespread. The eggs and larvae are long dead and gone before they get into the bay. I say it's time to stop speculating and get out there and take a look."

Congressional concern about the Chesapeake began in 1975 when Senator Charles Mathias (R., Md.) moved a bill through Congress authorizing the Environmental Protection Agency to do a five-year study of the Chesapeake's decline. At the time Senator Mathias said, "The bay is an organic whole. If one part is damaged, all parts are affected. It is of little use to study one link in an environmental chain without relating it to the whole. If the Chesapeake Bay is to survive, it must be addressed as an entity, as a total system without duplication and without omission."

The study eventually took seven years and was completed last September. It cost $27 million and documented degradation of the bay proper, but nowhere in its laundry list of problems did the EPA document any changes in pH levels in spawning rivers and streams, even though it seems apparent that the eggs and larvae are "long dead and gone" before they ever get into the bay. Last January, in his State of the Union address,

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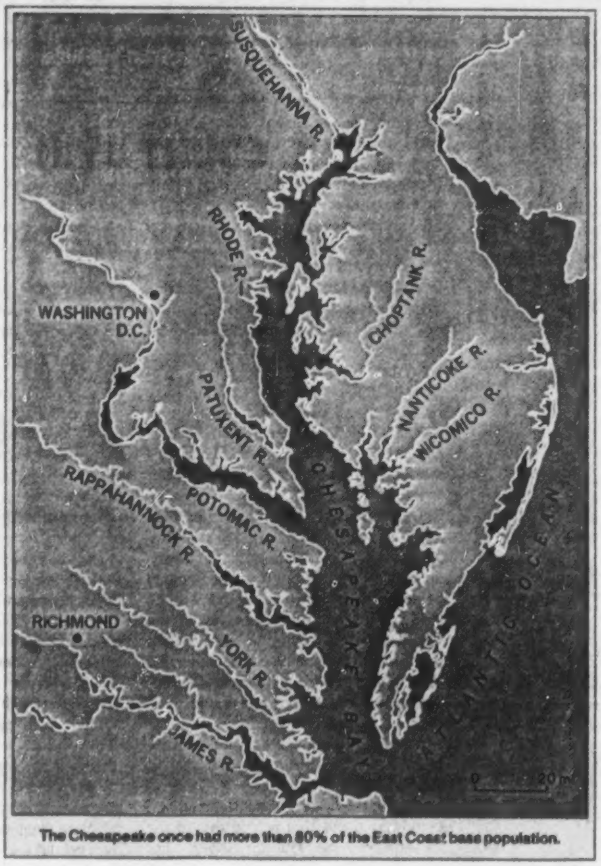
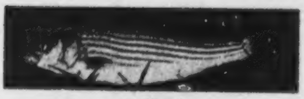
MAP BY NIKO TELAK



The Chesapeake once had more than 80% of the East Coast bass population.



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President Reagan promised to "begin the long and necessary effort to clean up a productive recreational area and a special national resource—the Chesapeake Bay." This may be difficult, since the President also has steadfastly refused to take remedial action on acid rain, asking instead for further study.

Specific Congressional concern about striped bass began in 1979 after Senator John Chafee (R., R.I.) read John N. Cole's book *Striper*, in which Cole predicted that the fish would eventually be done in by chemical contamination. Shortly thereafter, Chafee saw to it that Congress passed an amendment to the Anadromous Fish Conservation Act, which called for a $4 million Emergency Striped Bass Research Study (the final price tag was $5 million). This past February the biologists in charge of the study, Dr. John Boreman of the National Marine Fisheries Service and Dr. C. Phillip Goodyear of the U.S. Fish and Wildlife Service, presented a draft to Congress in which they concluded that "no single contaminant has been identified that can be considered responsible for the decline in the coastal stock." However, they noted, laboratory studies "suggest" that combinations of chemical contaminants "may be" contributing to the decline of early life stages. In addition, fishing "may be" inhibiting production. This report prompted Representative Schneider of Rhode Island, whose state declared a moratorium on striper fishing last year, to introduce her bill.

In the draft of their report, Boreman and Goodyear also mentioned that "investigators from the Maryland Department of Natural Resources documented pH levels in the range of 5.9 to 6.9 in the striped bass spawning grounds of the Choptank River during the 1983 spawning season. This observation is important because this range of pH is below the optimum for striped bass larvae and juveniles, and because low pH may alter the toxicity of contaminants in the environment, particularly the inorganics [such as aluminum]."

Also in the draft report, Boreman and Goodyear noted that in contrast to the Chesapeake, the Hudson River "has maintained a steady level of production since 1969," even though the Hudson stripers had the highest PCB levels of any bass tested, making them unfit for human consumption. They attribute this "apparent enigma"—the fecundity of the Hudson as opposed to the barrenness of the Chesapeake—to the fact that it's permissible to catch smaller stripers in the Chesapeake than in the Hudson; moreover, the Hudson commercial fishery has been closed to striped bass fishing since 1976 because of PCB contamination. The report fails to mention that the "enigma" of the Hudson also encompasses an abundance of other species besides striped bass, such as American shad, which are intensively fished for in the river, as opposed to the shad fishing ban in the Chesapeake since 1980. The most obvious explanation is that the spawning grounds for striped bass, shad and other fish in the Hudson are highly buffered by its extensive limestone beds—in 1983 the low pH was 7.5 and the high was 7.8—whereas rivers and streams in the Chesapeake are subject to acid pulses. Boreman now says, "That is a hypothesis we cannot contradict at this time."

This spring, Boreman and Goodyear say, the U.S. Fish and Wildlife Service's Fisheries Research Laboratory in Columbia, Md. will study the interactive effects of acidity, contaminants and other environmental variables on the survival of striped bass eggs, larvae and fingerlings. The state of Maryland will also be doing acidity research on spawning rivers, so by June of this year the hypothesis that acidic water and acid pulses are disrupting striped bass reproduction should have been tested. "Right now, there is strong circumstantial evidence," says W.R. (Nick) Carter III, Program Chief for Environmental Review of the DNR's Tidewater Administration. "We have seven species declining at once, and we know that we have strong acid precipitation occurring at times in Maryland. That's all we *know*."

There is a pause. Carter then says, "For three of the last four days, it's been raining here. The streams are warming up, and the fish are coming in to spawn. Sometimes when I think about what might be happening, I just want to curl right up and die." ■■■

United States Senate
WASHINGTON, D.C. 20510

November 17, 1983

The President
The White House
Washington, D.C. 20500

Dear Mr. President:

We are writing to express our concerns about the problem of acid rain.

As Westerners concerned with protection of our natural heritage, we share the concerns of the Northeast and are disturbed by the environmental damage being caused by acid precipitation. We do not agree that such damage to the environment is acceptable even though there may be no direct, adverse impact on human health. We believe the time has come to develop a sound federal policy for the control of acid rain, and we intend to work with others to develop such a policy.

At the same time, some of the current proposals for controlling acid rain, and financing such controls, are clearly bad policy. They are bad policy both taken alone and in light of the very unfortunate precedents they would set. We refer particularly to the "nationwide tax" and "mandatory scrubber" proposals.

A fundamental principle for dealing with environmental problems is that those who cause a problem should be required to pay for its cleanup. This principle assures that the true costs of combatting pollution are allocated fairly to the responsible parties and their consumers. Clearly, it is wholly violated by proposals for a "nationwide tax" to finance the control of acid precipitation. The Western states have already invested heavily in air pollution controls for power generation. Current SO2 emissions in the West represent only 3 percent of national SO2 emissions while the West produces 19 percent of the country's coal fired generated electricity. Since the problem is not evidenced to the same extent in the West, a "nationwide tax" would violate principles of fairness and efficiency by dictating that we in the West be required to pay to clean up a problem attributable largely to utilities outside our region.

Second, we see no reason to extend the shortsighted federal requirement that sulfur emissions be reduced using only expensive "scrubbers," even though in many instances necessary reductions in emissions may be achieved through more cost-effective alternatives. If the goal is to reduce sulfur emissions, utilities should be allowed to choose the most efficient method of reducing such emissions -- on a case-by-case basis. We see no reason why consumers should be forced to pay billions of dollars for unnecessary "scrubbers" to achieve equivalent environmental benefits. The nation's ability to invest in the environment is too limited to mandate such obvious waste.

We encourage you to press forward with efforts to identify a sound, farsighted strategy for dealing with acid rain. In our view, the approach chosen to this problem will set major precedents for dealing with future environmental risks. Serious efforts should be made to choose a strategy that is economically efficient and environmentally sound, and which therefore avoids panaceas such as a "nationwide tax" and "mandatory scrubbers." We ask that you not delay in leading the country to an equitable and cost-effective solution to the problem of acid precipitation.

Sincerely,

Dick Cheney
Member of Congress

Ray Kogovsek
Ray Kogovsek
Member of Congress

Jim McClure
James A. McClure
United States Senator

John Melcher
John Melcher
United States Senator

Jim Abdnor
James Abdnor
United States Senator

Malcolm Wallop
Malcolm Wallop
United States Senator

Max Baucus
Max Baucus
United States Senator

Pete V. Domenici
Pete V. Domenici
United States Senator

Alan K. Simpson
Alan K. Simpson
United States Senator

Bill Armstrong
William L. Armstrong
United States Senator

Edward Zorinsky
United States Senator

Chic Hecht
United States Senator

Steve Symms

Steven D. Symms
United States Senator

Jake Garn

Jake Garn
United States Senator

John McCain

John McCain
Member of Congress

Dan Schaefer

Dan Schaefer
Member of Congress

Mark O. Hatfield
United States Senator

Orrin Hatch

Orrin G. Hatch
United States Senator

Larry Pressler

Larry Pressler
United States Senator

Ron Marlenee

Ron Marlenee
Member of Congress

Charles Pashayan, Jr.
Member of Congress

Dan Marriott
Member of Congress

Howard C. Nielson
Member of Congress

Pat

Patricia Schroeder
Member of Congress

Louisville, Ky., Sunday morning, April 8, 1984

The Courier-Journal

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Region falls victim to own pollution, research indicates

By LARRY TYE

Courier-Journal Staff Writer

New scientific studies have documented extensive damage to trees and crops in Kentucky and neighboring states, and researchers say that air pollution may be to blame for much, if not most, of the problem.

The damage has been documented in urban areas and forests alike, from roadsides to farms to remote Appalachian mountaintops. If the research conclusions are correct, they may add a new dimension to the regional debate over air-pollution control measures — and may cast Kentucky for the first time as a victim, rather than a villain, in acid-rain and other pollution woes.

According to an Oak Ridge National Laboratory researcher, tree growth among red spruce in the Great Smoky Mountains has slowed 35 percent during the past 25 years. Existing trees aren't shooting up the way they should, and many new ones aren't surviving.

A University of Kentucky professor suspects air pollution is to blame for what he calls severe damage to vegetation in Kentucky. Although there has been little research on the cause, a special research project is about to begin to examine the role air pollution has played in that blight.

And a scientist from Butler University in Indianapolis has studied what he calls an epidemic of damage to vegetation in Louisville and other cities along the Ohio River.

Those findings seem to support a federal study released last year suggesting billions of dollars in damage each year to melons, soybeans, tobacco and other valuable cash crops nationwide. In Kentucky and Indiana, the loss is probably in the millions of dollars, the study said.

Most of the new research hasn't been published, but scientists recently began discussing their evidence of tree and crop damage.

A major suspect is "acid rain" — highly acidic rain caused when sulfur and nitrogen emissions from coal-burning plants and vehicles turn to acid at high elevations. Federal studies show that rain in Kentucky is as acidic as that in New England — both have pH, or acidity, levels of 4.1 to 4.4, about the same as tomato juice.

The debate over whether a national plan is needed to control acid rain has snagged on questions about the cause and extent of damage, and whether pollution travels from coal-burning regions such as the Ohio River Valley to areas as far away as Canada and the northeastern United States, where damage has been extensive. Kentucky and other Ohio Valley states, believing they were immune from damage, have resisted expensive emissions controls.

But now researchers report similar damage around the Ohio Valley.

"It's quite important that the people of Appalachia understand that the forests of Appalachia appear to be in as much danger as the lakes of New England," warned David Freeman, former chairman and now a board member of the Tennessee Valley Authority. "Once people understand the facts they'll see there is no conflict of interest between us and New England.

"This is fundamental to break up the political stalemate on (acid-rain) legislation."

In the Great Smoky Mountains National Park, 8 million visitors each year could — if they knew what to look for — see damage to trees.

The symptoms are clearest in the red spruce that dominate higher elevations — places like 5,000-foot Newfound Gap, 13 miles south of Gatlinburg, Tenn., a favorite for cross-country skiers and hikers.

Peering down into the surrounding forest, one sees thinned crowns, yellower-than-normal needles — and barren tree tops. Where healthy trees stand next to ill ones, the devastation is even more obvious. This is one of the few places where red spruce are found in this part of the country, but researchers warn that, if trends persist, the spruce won't be around long.

The disease also has attacked firs and other species.

Dr. Sandy McLaughlin, a forest scientist at Oak Ridge National Laboratory who is studying tree damage in the Smokies for the U.S. Environmental Protection Agency, said he has found that red spruce growth has been cut by 35 percent during the past decade.

He reached that conclusion by drilling out long, thin tree cores and studying the distance between annual growth rings. McLaughlin has documented a dramatic slowing of growth in the past 25 years — for fraser firs, hemlock, shortleaf pine and yellow birch as well as red spruce.

"We cannot conclude at this time that air pollution has or has not caused these changes," he said. Bad climate or competition between species could also be at fault.

But his core drillings have turned up metals and other chemicals that he said probably came from acid rain or other air pollutants — and pollution concentrations were greatest when growth was slowest. That makes air pollution "one of the strong contenders in the search for causes," McLaughlin said.

In Kentucky, Tom Kimmerer, a UK forestry professor, said he has observed "severe" leaf damage "throughout the Bluegrass, Western Kentucky and Louisville" — with cottonwood, oak and pine the hardest hit. And he warns that anywhere in the state people see damaged trees pollution may have been the cause.

But no one has measured just how bad the tree damage is or just where it occurs.

"Kentucky is sort of a black hole on air pollution," Kimmerer said. "I'm the only person doing any research on how air pollution works on plants."

But that will soon change: The U.S. Environmental Protection Agency awarded UK $180,000 last week to study pollution damage to forests and crops, with three years of work due to begin this summer.

UK researchers are just beginning to test the leaves of damaged trees to document how much of a role pollution played. If any of three chemicals — ethylene, acetaldehyde or ethanol, all produced by leaves suffering from pollution stress — are found, Kimmerer said there is a strong possibility pollution, rather than drought or insects, was responsible. Regardless, he thinks pollutants make trees more susceptible to other kinds of damage.

And he thinks the biggest culprit in Kentucky is ozone — the major component of smog, produced when the sun heats car and factory emissions.

"Based on measurements of ozone levels in this state, there is every reason to believe" that air pollution significantly affects forests, he said. "Ozone is more significant here than acid rain, but the two things often occur together."

However, Dr. Orie Loucks, director of Butler University's Holcomb Research Institute, said he believes the worst offender is sulfur pollution that hangs in the air as summertime haze. This moisture — which can be up to 1 million times more acidic than acid rain, or 80 times more acidic than battery acid — gradually builds up on leaves, killing the trees.

And one does not have to climb a mountain or tramp through fields to find the damage: Evidence abounds on trees lining the streets in Louisville, Indianapolis and dozens of communities along the Ohio River, Loucks said.

He thinks the damage has reached "epidemic" proportions among cone-bearing trees in the Ohio Valley. And he says problems in the region — such as yellowing, thinning and loss of leaves in white pines, yellow poplars, sycamores, white ash, maples, oak and possibly other species — are much worse than he and other researchers have seen in New England.

All of this damage has not escaped the notice of landowners in the region. James Cole, who at 70 still spends his days farming and keeping run a saw mill, has watched for three decades as air pollution in Indiana attacked trees on his land in Leavenworth, near the mouth of the Blue River.

"I read about the troubles they had in London back in the 1950s because of this acid rain business," he said. "As the Ohio Valley increased in high-sulfur coal consuming industries, I have noticed the trees and plants have been showing stress. The ones that had such a hard time growing here in the first place — like white walnut or butternut — just almost disappeared.

"When I was little boy I had a good crop of butternuts almost every year, and some trees grew to 2½ feet in diameter. Now you can hardly find a butternut tree on my property.

"I think if we don't do something, we in the Ohio Valley are going to be left out when it comes to trees and plants in the future."

Air pollutants also have caused major crop losses, scientists say.

Last summer the problem was particularly severe, killing watermelons and cantaloupes near Vincennes, Ind., said Dr. Walter Heck of the U.S. Department of Agriculture. When ozone, sulfur dioxide and nitrogen combine, "we see greater effects than when any one of them is there alone."

Joe Huber, president of the Indiana Vegetable Growers Association, said farmers initially thought powdery mildew disease was responsible for melon damage. But after extensive study by scientists from the Department of Agriculture and Purdue University, "we all came to the same conclusion: Air pollution was causing all the problems we've had over the last three years."

Soybeans, tobacco, alfalfa, wheat and oats also are being hurt, Heck said. Nationwide, he said, EPA and Agriculture Department studies published last year show that air pollution is killing $2 billion to $4 billion in crops annually.

The scientists studying pollution's effects on trees and crops agree that more research is needed. But they also say reducing pollution will help.

"At the rate we're going," Loucks said, "we could have a great deal more mortality before we have done anything."

The debate should also be conducted in new terms in Kentucky and Indiana — focusing on the benefits rather than the costs of controlling sulfur and nitrogen emissions, he said. The benefits — in renewed vigor of crops and trees and a better quality of life — "are greater for us than for anybody out of our region."

Kimmerer concurs. "As Midwestern states start to see more crop and forest damage, people will realize that air pollution in general has got to come down. Given Kentucky's history on the environment, we'll be one of the last states to come to that view."

But there is no evidence of movement on the issue among Kentucky politicians.

The state's two Democratic senators, Wendell Ford and Walter "Dee" Huddleston, say they'll continue pushing for more research on the effects of air pollution — but will resist new action to cut emissions.

And Charlotte Baldwin, Kentucky's new natural resources secretary, said "I'm not aware of any evidence substantiating the damage as being totally due to acid rain."

Loucks, however, thinks there's a greater worry. He says pollution that is killing trees could be hurting people.

"We used to take canaries into coal mines and, so long as they were healthy, people could stay in the mines. We should view crop damage in similar terms. So long as they're healthy our future is assured. But when there is widespread impairment we should be very concerned."

The Courier-Journal
MAGAZINE
AMERICAS

America's shame: a special report

Today's Magazine features a special report by Larry Tye, The Courier-Journal's environmental writer. The report — based on months of research, including a monthlong visit to Europe — examines how the United States has relinquished its traditional leadership as the guardian of natural resources. At the same time, it shows how other nations have aggressively moved to clean up their problems — and how the lessons they've learned can be applied here.

APPENDIX C

Answers to Questions Submitted to The Honorable William D. Ruckelshaus, Administrator, Environmental Protection Agency

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 14 1984

OFFICE OF
EXTERNAL AFFAIRS

Official Committee File

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
JUN 14 1984

Honorable James A. McClure
Chairman
Committee on Energy and Natural Resources
United States Senate
Washington D.C. 20510

Dear Mr. Chairman:

Enclosed is the response of the Environmental Protection Agency to 31 questions on acid rain that were submitted following an April 30 hearing on the Acid Precipitation Act of 1980.

Sincerely

Steadman M. Overman
Steadman M. Overman
Director, Office of
Legislative Analysis

Enclosure

cc: Richard Grundy

Questions Submitted to Administrator William D. Ruckelshaus by the House Committee on Energy and Natural Resources

1. What is the scientific consensus on the natural pH of rain? Are there any studies which claim the natural pH of rain is from 3.6 pH to pH 5?

Annual average (precipitation weighted) pH values as low as 5.1 were reported in some remote areas of the world in 1982. These measurements demonstrate that a pH of 5.6, often considered normal for rainfall in the absence of pollution, cannot be considered a benchmark for comparison purposes. Organic acids are believed responsible for depressing the normal pH to a value closer to 5.0 than the expected 5.6. The origins of of these organic acids are presumed to be primarily from natural sources.

Airborne soil particles play an undetermined role in neutralizing the acidity of rainfall, but the presence of those soils could well explain the fact that the annual average rainfall in the upper midwest is above 6.0. It has been postulated that it is the changes in the soil component of atmospheric dust that accounted for the change in the acidity of precipitation reported in the scientific literature.

2. Have any scientific theories been advanced which indicate that acid deposition is not due to SO_2 or NO_x emissions from manmade sources, but rather to things like the acids in soils, or other factors such as non-chemical factors? If there are such theories are they generally accepted in the scientific community?

Natural sources of SO_2 in eastern North America are estimated to be from 1% to 10% of anthropogenic sulfur emissions. Natural sources of NO_x in eastern North America are estimated to be from 10% to 40% of anthropogenic NO_x emissions. Acidification of surface waters has been suggested to be caused by natural soil acidity. Many forest soils naturally acidify over long periods of time as a result of natural soil forming processes. Organic acids produced in these soils cause this acidification. These organic acids can be leached into surface waters and cause acidification. The surface water would have a brown color, however, as a result of this form of acidification.

Those lakes which have been identified as acidic due to acid deposition do not have a brown color indicating that the acidification is not from organic acids. These acidified surface waters have high levels of sulfate suggesting that the acidity is from acidic deposition. Also, nitrate has been shown to be related to acidification in these waters, again as a result of acidic deposition.

Therefore, acidification can result, in certain limited cases, from soil organic acids, but acid deposition is thought to be the cause in cases of acidified clear water lakes.

3. Is there any direct link between emissions of SO_2 and damage to human health, crops, soils, forests or surface waters? What do we know about the status of the science in these areas, and what research needs to be done before we have answers upon which policy decisions might be made? What are the scientific uncertainties?

Gaseous SO_2 is known to be toxic to humans and vegetation at high concentrations but not at concentrations present in ambient air that is in compliance with ambient air standards. The links between the emission of SO_2 in gaseous form, acidic deposition, and effects on human health and the environment are not known in their entirety. SO_2 can be transformed chemically in the atmosphere to sulfuric acid, which is a major component of acidic deposition. Acidic deposition appears to have effects on surface waters, and aquatic biota. It may have effects on soils and terrestrial vegetation, and some possibility of indirect impact on human health. However, the scientific uncertainties in each of these processes are significant. There are questions of the rate of chemical transformation, the distance over which these chemicals may travel in the atmosphere, the contribution of natural sources of sulfate, the actual rates of deposition in wet and dry forms, the extent of changes in aquatic and terrestrial systems, and the actual mechanisms of those changes and the extent to which acidic deposition is actually a cause of environment changes observed in the environment. Under the National Acid Precipitation Assessment Program, EPA is sponsoring extensive scientific research into all these questions in an effort to resolve the major scientific uncertainties that bear on important policy questions. There should be no doubt the acid deposition is a real and serious problem. However, until we have a better understanding of the details associated with the problem, we are not in a position to decide with reasonable confidence what additional actions should be taken.

4. Do we know how much damage has occurred that is attributable to acid deposition and the rate at which it is occurring?

No. We do not know how much damage has occurred from acid deposition on sensitive resources. A damage assessment is currently being performed by the NAPAP Task Force and its first report is scheduled for completion in 1985. Damage to lakes and streams from acid deposition is more certain than for other resources although the number of acidic lakes is small. The NAS Panel on Processes of Lake Acidification concluded that "streams and lakes acidified by acid deposition have a different biotic structure than non-acidified streams and lakes." Additionally, acid deposition may result in damage to materials and possibly damage to forests. Damage to crops would appear to be small. Most importantly little is known about the rates of damage. This is a crucial factor in determining the need and urgency for acid rain control actions.

5. **How do cations influence acidity levels?**

If cations such as H^+ and AL^{+3} are leached from soils to surface waters then their concentration in surface water can increase. If the process persists long enough and at a sufficient rate it can result in the production of acidic surface waters. Leaching of base cations (e.g. Ca^{+2}, Mg^{+2}, Na^+, K^+) does not acidify surface waters. Leaching of these cations indicates that acidic inputs are being neutralized in soils and watersheds.

6. Is there any scientific evidence showing sulfate levels are reducing over time in any particular region of the country? What do we know about trends of acid deposition and the rates at which it is occurring?

Over the last 20 years, sulfate levels in particulates have shown a general decline in urban areas. In non-urban areas, however particulate sulfate levels have tended to increase, especially during the summer months. This trend is most pronounced in the Eastern U.S. There is no comparable time series for sulfates precipitation. A recent USGS report indicated that the increase in acidification of precipitation in the Northeast occurred primarily by the mid 1950's and has been largely stable since the 1960's.

Since extensive wet deposition monitoring networks went into operation in 1978 there has been no clear trend in the sulfate loadings. However, there is a significant year to year variation in the data, caused by weather fluctuations and other factors, which may be masking a trend upward or downward in sulfate. This can only be established after several years of consecutive monitoring.

Data for the period July 1980 - June 1981 show that annual sulfate loadings exceeded $2g/m^2$ for the Northeast states, and was greater than about 3.5 for Indiana, Ohio and Pennsylvania. The highest loading was 4.7 for Ohio. Comparable patterns were found for Southeastern Canada.

The dry deposition rates were not measured, but it has been estimated that over the region, this could be equal in magnitude to wet deposition rates.

7. Is there any scientific consensus on the relative contribution of long range transport of acid deposition as compared to that of local sources? What is the relevance of knowing the answer to this question in instituting an acid rain control program?

The scientific consensus that exists on the relative contribution of long range transport of acid deposition precursors as compared to that of local sources is found in the National Research Council Acid Deposition Report (June 1983) and the U.S. EPA Critical Assessment Review Papers on Atmospheric Processes (May 1983). The NRC Report concluded the following:

"Theoretical and observational evidence exists for the long range transport of air pollutants leading to acid deposition. However, the relative importance for deposition at specific sites of long-range transport from distant sources as compared with more direct influences of local sources cannot be determined from currently available data or reliably estimated from current models."

"Available meteorological analyses of trajectories of precipitating systems at three locations in the northeast (Whiteface Mountain and Ithaca, New York and south central Ontario) indicated that much of the acidity in precipitation - as well as much of the precipitation comes from air masses arriving from the south and southwest."

".... it appears that the atmospheric processes in eastern North America lead to a thorough mixing of pollutants, making it difficult to distinguish between the effects of distant and local sources."

The relevance of knowing the answer to this question in instituting an acid ran control program is determining (1) how large an area needs to be controlled and (2) the benefits of controlling particular groups of sources or individual sources.

8. Is acid deposition getting worse over time in any particular region of the nation?

There is not yet a long enough time series of acid deposition to establish a clear trend. Data from any specific monitoring site may vary greatly from year to year because of local fluctuation in participation patterns.

9. What were the findings of the Hubbard Brook Study?

The findings of research projects at Hubbard Brook have been published in dozens of scientific papers and many books. Researchers have investigated a variety of topics at this watershed. The results of all of these studies can not be summarized here. One of the more pertinent studies, however, is the record of wet deposition at the site. Results indicate that over the last 20 years sulfate, nitrate and acidity deposition have decreased, increased, and remained constant, respectively. The sulfate decrease corresponds to decreased SO2 emissions and the nitrate increase to greater NOx emissions. The net result is no change in acidity.

10. Is there any scientific evidence to show a relationship between SO_2 and NO_x and other aerosol concentrations in the atmosphere? What is the relevance of any relationship between these elements in terms of efforts to institute as acid rain emissions control rollback program in this country?

There is scientific evidence to show a relationship between SO_2 and NO_x emissions and aerosol SO_4^{2-} and NO_3^- concentrations on a local and regional scale. This evidence is found in the annual EPA National Air Quality and Emission Trends reports and the EPRI Sulfate Regional Experiment (SURE) program report, as well as in the general scientific literature. However, these emission-air quality relationships, especially on a regional scale, have not been adequately quantified, especially taking into account the effects of year-to-year variabilities in meteorological processes like long range transport and precipitation. With regard to the use of these "regional emission-air quality relationships" in an acid rain emissions rollback control program, they are thought to have some applicability to what will happen to dry-acidic deposition if emissions are reduced. The NRC report concluded the following:

"If dry deposition is linearly proportionate to emissions, as suggested in the section on principal-component analysis, then the annual average ratio in bulk (wet + dry) deposition in the area should also respond to changes in the emission ratio (SO_2/NO_2) (if the spatial distribution of emissions is unchanged, i.e., uniform rollback)."

However, the NRC report also concluded:
"Without greater confidence in the results of deterministic models, we cannot judge the consequences of emission reductions in a smaller region, such as the Midwest, for deposition (wet or dry) in another region, such as the Adirondacks or southern Ontario.

11. Is there any scientific evidence to indicate the natural acidity of the soils is really causing acidity in the water reaching lakes in the Adirondacks?

A majority of the lakes identified as acidic in the Adirondacks are clear water lakes, low in organic acids. If organic acids (natural acidity) had caused the acidity the lakes would be brown in color. Also, sulfate levels would be expected to be low. Sulfate levels are high in the acidified Adirondack waters indicating that acidic deposition is a major contributor.

High inputs of nitrate have been found in Adirondack streams at certain times of the years (e.g. snowmelt) contributing to acidification, again as a result of acidic deposition. There are theories to indicate that the acidification of lakes can be the result of natural processes or of land use changes. The National Acid Precipitation Assessment Program (NAPAP) is investigating these hypotheses.

12. Is there any scientific consensus on the contribution of natural SO_2 deposition as compared to man-made sources? What estimates are there, if any?

There exists a fairly wide range of views in the scientific community on the possible importance of natural sources for the deposition of acidic materials in some regions of the country and globally. Consensus generally exists on the following points:

- Global natural sulfur emissions are estimated to be 1/2 to 2 times anthropogenic (man caused) emissions.
- Natural emissions on sulfur in eastern North America are estimated to be from 1% to 10% of anthropogenic sulfur emissions.
- Substantial uncertainty exists regarding natural sulfur emission rates in most regions of North America, including offshore, and the relative contribution these make to acid deposition on potentially sensitive areas.
- Global natural sulfur emissions may primarily be marine in origin from dimethyl sulfide production in biologically productive waters; but the strength of this source is highly uncertain, as is its contribution to sulfur deposition on continental land masses.
- Natural sources of NO_x in eastern North America are estimated to be from 10% to 40% of anthropogenic NO_x emissions.
- Substantial uncertainty exists regarding natural NO_x emission rates in most regions of North America and the relative contribution these make to acid deposition on potentially sensitive areas.
- Global natural NO_x are estimated to be 1/2 to 3 times anthropogenic emissions.
- Anthropogenic activity (e.g. farming, grazing and silviculture) can strongly affect the amount of NO_x emissions from "natural" sources.
- Emissions from natural sources of ammonia, alkaline dust, reactive hydrocarbon and other atmospheric constituents are poorly described, and a meaningful quantification of their relative importance to anthropogenic sources is not possible at this time.

13. How many lakes are there in acid deposition sensitive regions of the Northeast? Of these, how many are acidic and incapable of sustaining aquatic life? Of the acidic lakes, can they be biologically revived by liming, and if so, at what cost?

There are approximately 13,000 lakes of all sizes and conditions in the Adirondacks and New England. Of these, approximately 200 are known to be acidic ($pH < 5.0$), and more may be, but have not been sampled yet. Liming these acidic lakes is possible in some cases, and could reduce acidity for several years, providing the possibility of the return of fisheries. However, many of these lakes are remote, and the cost of liming them is likely to be quite high. Furthermore, the long-term effects of liming on the biological health of lakes are not yet known.

EPA is sponsoring research under the National Acid Precipitation Assessment Program that is investigating these issues. The National Aquatic Survey will provide us with an estimate of the number of lakes in this region, their water quality and locations. EPA, in conjunction with the Fish and Wildlife Service also sponsors extensive research on the effects and costs of liming programs, also within NAPAP.

14. How many lakes in the Eastern U.S. are not threatened by acid deposition due to a high buffering capacity of the soil?

Out of the 13,000 lakes in the New York/New England area, approximately 200 are known to be acidic (pH < 5.0), and an additional few hundred are estimated to also be acidic. Thus, in this region, our best current estimate is that over 12,000 lakes are not acidic. This represents a judgment based on a general understanding of the acidification processes and not a statistically based analysis. Current research conducted by EPA under the National Acid Precipitation Assessment Program is targeted towards discerning the factors that influence the rate at which lakes respond to acidic deposition. If a large fraction of these lakes are currently in chemical equilibrium with respect to sulfate inputs (i.e. exhibit a direct response), then they will not show further degradation as long as sulfur deposition remains constant. Those that exhibit a delayed response may become acidified, but the extent to which they are buffered by watershed soil characteristics is an unanswered question. EPA is sponsoring two tracks of research to answer these questions. First, the National Aquatic Survey will provide a synoptic picture of the number of lakes in the U.S., how many of those are acidic, and where they are. Second, significant new research into the questions of delayed/direct response will provide us with the capability to predict how many lakes of each type there are, and to predict changes we would expect in those lakes as well as the rate at which those changes might occur. The current state of scientific knowledge does not allow us to make a quantitative estimate of the number of lakes that are protected by high soil buffering capacity.

15. What is the average size of the acidic lakes in the Northeast as compared to those which are not acidic?

The average area of an acidic lake in the Northeast is approximately 40 acres, based on a sample of 110 acidic lakes in the Adirondacks. The range of areas is quite large (4-818 acres). Based on the estimated total area of lakes in the New York/New England region and the estimated total number of lakes in that region, the average size of a lake is approximately 190 acres (this estimate does not include Lake Champlain). Thus, on average, acidic lakes seem to be small.

16. What do we know about the rates of change in the chemistry of lakes and streams, or biota or fish as a direct result of acid deposition?

We know very little. There have been a number of studies published on changes of water chemistry or biota over time, but it is rarely unambiguously clear that these changes are a direct result of acidic deposition. Further complicating the question is the fact that many of the data are not continuous over time so that rates cannot be calculated in a meaningful way. Complete discussions of changes with time have been presented in the Critical Assessment Review Papers (CARP). Current NAPAP studies are gathering data in a fashion that will allow the future determination of rates of change.

17. Do we know whether or not acidification is at a fixed point in acid deposition sensitive areas, or whether it will continue to degrade aquatic and terrestrial ecosystems at a rapid rate? Are there any alternative scientific theories on this point? If so, how are they relevant to whether or not an acid rain control program must be instituted at this time?

At the Administrator's request a panel of the National Academy of Sciences was convened to review the current understanding of the mechanisms of surface water acidification caused by acid deposition. The Academy has completed this work and recently released their final report. Although there was not a total agreement between members of the panel it would seem the general conclusion is that the two hypothesis (rapid response and delayed response) previously identified by the agency are in fact two parts of an over all process of acidification. Under this unified hypothesis, the rate and extent of surface waters acidification is a consequence of two main factors: (1) the rate and amount of acid deposition and (2) the chemical and physical properties of the particular watershed in question. Severe acidification of a lake - (the effect or real concern) takes place when the rate of deposition is high and the assimilation capacity of the watershed is low. When the Academy panel looked at the specific mechanisms involved in this interaction they reached some important conclusions about what would happen if deposition were to continue at its current rate. If acid deposition were to continue in watersheds whose soil has a high capacity to either neutralize or adsorb acid deposition, it is unlikely that significant additional harm would result during the next few decades. Likewise, neither would there be increased damage to those watersheds whose rate of acidification is at dynamic equilibrium with their rate of acid deposition. This condition occurs when all of the readily available neutralizing material in the soil is consumed and the only source of neutralizing material is that released by weathering of rock material found in soil and land surface. Since the acid deposition accelerates the rate of weathering a dynamic equilibrium between deposition rate and weathering rate is established.

Continued deposition could however adversely affect watersheds whose acid neutralizing or sulfate absorptive capacity is limited and not readily renewed. In these systems, additional deposition can exhaust the assimilative capacity resulting in increased lake acidification until new equilibrium is established with the weathering process. Unfortunately, the academy could give little guidance as to the number of watersheds that fall in this potential risk category. The Academy report recommends research which would help us to overcome the major gaps in our understanding of the scope and pace of surface water acidification.

18. **Are the concentrations of either SO_2 or NO_x emissions relevant to curbing the amount of acid deposition which falls in a particularly sensitive region of the country such as the Adirondacks?**

The concentrations of SO_2 and NO_2 have some relevance to the amount of acid deposition which falls in a particularly sensitive region of the country such as the Adirondacks. However, a quantitative relationship between ambient concentrations of SO_2 and NO_2 and wet and dry acidic deposition is not available for which there is a scientific consensus. It is generally agreed that dry desposition can be calculated from the ambient concentration and an empirically determined "deposition velocity"; however, the latter is subject to considerable uncertainty and the measurements of the former are extremely limited, especially in sensitive areas like the Adirondacks. The wet deposition has also been calculated from the ambient concentration, the precipitation rate, and an empirically determined "scavenging coefficient"; however the latter is also subject to considerable uncertainty.

19. What is the relationship between sulfate deposition and trends for SO_x and NO_x? Is this relevant to on the linearity/non-linearity debate between the National Academy of Science and the National Labs? What is the relevance for these two theories on an acid rain control program of 10M tons rollback in SO_2 emissions in the Midwest?

The nature of the relationship between emission of a given pollutant and its subsequent deposition is indeed the subject of intense debate and research, especially for wet deposition. The National Academy of Sciences report proposed that a linear relationship was a reasonable estimate for sulfate, primarily because the authors were unable to demonstrate the existence of a non-linear relationship. The National Laboratories' review pointed out that the evidence used in this analysis is subject to alternative interpretations and conclusions and to constraints on temporal and spatial applicability. The two groups have since agreed that for large spatial scales, (such as eastern North America) and long averaging times (ca. 1 year), that aggregate deposition may be proportional to aggregate emissions is a reasonable hypothesis, yet to be proven, but that this hypothesis is not reasonable for specific receptors of interests under special scales or for shorter time periods.

The relevance of this uncertainty to the design of control programs relates to their efficiency. Reducing emissions is indeed likely to result in reduced deposition, but our ability to target specific receptors and emitting regions is limited by this fundamental lack of understanding. Since we also know that deposition from a specific source is likely to be most important relatively near that source (10-100 km), and since there are wide geographic differences in both receptor sensitivity and the costs of controls of specific sources, this lack of detailed understanding is a major impediment to effective control strategy design.

20. Is the status of the acid rain research such that we know whether or not and in what way acid deposition is contributing to the decline of forest growth?

We do not know with any certainty whether or not acidic deposition is a contributor to the reported decline in growth rates of some forest tree species. The reported growth declines, based on preliminary data, do occur in areas that are known to receive acidic deposition although the rate of deposition is highly variable over the area. The trees in these areas are also subject to drought and many other natural causes of decreased growth rates, as well as other associated air pollutants, such as ozone, SO_2, NO_x, and metals. EPA, within the National Acid Precipitation Assessment Program, is sponsoring intensive research to determine both the extent of forest growth decline across the country, and especially to determine the causes of the decline. Several hypotheses exist, from direct foliar effects of ozone and SO_2, to overnitrification, to alteration of mycorrhizal symbionts, but there is currently no way to distinguish among them in the field. Testing and validating of this hypotheses is an important task of the current EPA research program.

21. Is there any evidence to support a theory of combined pollutant effects on foliage rather than through soil processes in the root zone? What does the difference mean in terms of SO_2 emission controls from long range as opposed to short range sources from man-made emissions?

Ozone and other pollutants, such as SO_2, are known to damage plant foliar tissues. However, whether or not this is occurring in forests showing reduced growth, or in red spruce showing dieback symptoms is at present not known. Direct foliar effects are one hypothesis among several for mechanisms of damage. The current state of research does not allow us to distinguish among these hypotheses, or even to determine if some combination of them might be true in some forests.

SO_2 concentrations are likely to be more highly correlated with short-range sources. However, the precursors for ozone formation may be transported hundreds of miles downwind before they react. Likewise, if sulfate or hydrogen ions from acidic deposition have direct foliar effects, transport distances may be long. Thus, the implications for control strategies depend on the elucidation of actual mechanisms of damage to forest trees.

22. Is there any direct scientific evidence linking acid deposition to forest damage? What about scientific studies which indicate the cause of tree damage to German forests is directly caused by ozone attack on the needles, possibly in combination with SO_2, NO_x, or both? What studies suggest that more than one mechanism could be contributing to the cause of tree damage?

In the U.S., we do not know the causes of growth decline in some forest trees, nor do we know the causes of the dieback symptoms seen in red spruce at high elevations in the East. We suspect that air pollution may be involved in some way, but the relative contributions of acidic deposition, metal deposition, ozone, SO_2 concentrations, drought, insect attack and other natural factors cannot currently be defined. EPA sponsored research, within the National Acid Precipitation Assessment Program, is targeted toward providing answers to the questions of damage mechanisms.

In Germany, where damage to the forests is far greater, the mechanisms of damage are also not known with certainty. Several hypotheses, including direct foliar effects of ozone and other pollutants, have been proposed. Loss of calcium and magnesium and increased levels of aluminum in the soils have also been proposed. It is quite likely that more than one mechanism operates in different parts of the country, under different pollution levels and with different soil types.

Here, mechanistic soil and plant research now underway is planned to aid in elucidating how specific environmental stresses may cause forest growth declines. EPA is sponsoring research that examines the interactive effects of acid rain, gaseous pollutants and other environmental stresses on plant growth. We also have research underway on the effects of acidic deposition on sensitive life stages and critical processes of plant growth and reproduction. Aluminum effects on tree species are also being investigated, as well as many other soil processes that may be affected by acidic deposition.

23. Is damage from acid deposition being experienced in parts of the United States other than the Northeast, as is suggested by the recent National Wildlife Federation Report? Do you agree with the conclusions reached in this report? If not, why not? Is there scientific consensus to support the conclusions reached in the study?

Unfortunately, our current understanding of the occurrence and consequences of acid deposition are for the most part limited to the northeastern United States. We do know that the northeastern quarter of the United States has the greatest concentration of SO_2 sources and appears to have the highest levels of deposition. Consequently, the sensitive areas of the northeast would appear to be the areas of greatest risk from acid deposition damage. Sensitive areas in other parts of the United States would appear to be less threatened because of lower levels of deposition.

We have reviewed the recent report of the National Wildlife Federation and based upon the data and arguments presented there, do not feel that a scientifically credible case has been made for wide spread damage outside of those areas previously identified in the northeastern United States. This is not to say that no damage may be occurring in the areas identified by the report, but rather we believe a much more rigorous analysis and broader base of information would be needed to adequately support the NWF's conclusions. Our current efforts with a National Lake Survey, a National Terrestrial Survey and an expanded deposition monitoring network should help fill part of this information gap.

24. **What do we know about the causes and effects of acid deposition, and where is the science yet uncertain? When might we have some answers to the areas of scientific uncertainty, and how will the answers to these issue areas affect our ability to deal with the problem of acid deposition?**

The broad subject of the state-of-knowledge about the causes and effects of acid depositon has been summarized in the EPA Critical Assessment Review Papers and by two NAS panels on atmospheric and lake acidification processes. A third NAS Panel is currently assessing the state of knowledge on trends in deposition while the NAPAP is preparing an assessment for release in 1985.

There are four general areas of scientific uncertainty that have been identified, namely (1) the scope of the problem (i.e., the number of lakes, acres of forests, and materials that have been affected); (2) the rate of past, present and future damage from acid deposition; (3) the source-receptor problem (i.e., the impact of specific sources or source regions on specific receptors); and (4) the mechanisms of damage.

Since it is not possible to predict what the answers from the research program will be or when they will be forthcoming, it is not possible to tell when a decision could be made or what that decision might be regarding the need for additional emission controls. However, the NAPAP program and EPA's own ongoing policy reassessment is focused to reduce these critical uncertainties, provide answers as soon as possible, evaluate these answers for their policy implications and communicate these facts and findings to decision makers in a timely manner.

25. What is the temporal and spatial distribution of acid deposition?

The levels of pH in wet deposition are generally lowest (most acidic) in summer time. In the period of July 1980 - June 1981, the 4.2 pH contour enclosed all of Ohio, Pennsylvania, W. Virginia and Indiana, and most of upstate New York, and Eastern Kentucky. The 4.5 contour line enclosed all of the U.S. east of the Mississippi with the exception of Florida, Mississippi and Southern Georgia and Alabama. The lowest levels of pH (4.1) were measured in Ohio, W. Pennsylvania and W. New York.

26. What are the latest studies of soils as they relate to acid deposition and tree damage, and what are the various theories of how acids are transported through pathways in the soil to lakes and tree roots? Does the soil itself, and the level of its acidity or buffering capacity make a difference in whether or not tree roots are damaged or lakes become acidic?

Soil microbial, chemical, and physical characteristics have not been shown to be adversely affected by acidic deposition. Long-term changes may be occurring, however, which are difficult to detect. Alterations (inhibition, stimulation) of soil microbial activity have been shown in some laboratory experiments with high levels of acidity. These effects may be largely artifacts of the method of application. Important effects of acidic deposition under field conditions on microbial processes have not been determined.

Alterations in soil chemical or physical characteristics have not been found under field conditions. There is no evidence that acidic deposition results in acidification of soils (soil solutions can, however, be acidified); at most, it makes only a minor contribution compared to natural acidification processes. Although acidic deposition may accelerate the loss of cations from soils, the significance of losses is presently unknown, but is thought to be minor in most cases.

Though soils may be relatively unaffected by acidic deposition, soil solutions and surface waters may be affected. Potentially, aluminum mobilization into surface waters from soils may be increased by acidic deposition in some watersheds without changes in soil chemical properties. Aluminum mobilization could also adversely affect terrestrial vegetation. The effects on soil solutions would be reversible; i.e., decreases in acidic deposition would be expected to lead to a return to "normal" conditions.

27. What are the cost estimates for the controls under these varying scenarios, including, in addition to things like compliance costs for scrubbers, coal switching, increased electric generating consumer costs, and energy impact, associated job losses?

a) S. 768
b) H.R. 3400
c) H.R. 4404

EPA, working with a contractor, ICF, Inc., has conducted detailed cost analyses of S. 768 and H.R. 3400. The resulting reports are enclosed. The Agency has not analyzed H.R. 4404 or the recently amended version of S. 768 which requires additional reductions.

Both H.R. 3400 and S.768 would result in 1995 SO_2 emission reductions of roughly 9.5 million tons below projected levels. Compared to 1980 emission levels the reductions are approximately 8 million tons.

We estimate that under S. 768 these reductions could be attained at an annualized 1995 cost of $3.5 billion (expressed in 1982 dollars). In the case of H.R. 3400, the 1995 annualized cost would be $4.2 billion. The average electricity rate increase would be about 3 percent for both S. 768 (31 states) and H.R. 3400 (48 states). The maximum statewide increase would be 9 percent for S. 768 and 7 percent for H.R. 3400. Some utilities and rate-payers would experience considerably larger rate increases. The magnitude would depend on compliance methods selected and Public Utility Commission ratemaking practices. In both cases we assumed that the bills were implemented in a least-cost manner--i.e., to the extent that governors were given the flexibility to allocate reductions among sources, they chose to minimize their state's total cost of compliance.

From a national perspective, neither bill would result in significant net job losses. Total coal mining employment will rise from 230,000 in 1980 to about 350,000 in 1995 whether or not acid rain controls are enacted. However, there would be shifts in mining employment between regions. These job shifts are generally from high sulfur coal regions in Northern Appalachia and the Midwest to low sulfur coal regions in Central Appalachia and the West.

We estimate that on a regional basis, H.R. 3400 would not result in mining job losses relative to 1980 employment levels. However, compared to projected 1995 employment levels, there could be as many as 3000 job switches from high to low sulfur coal regions. In the case of S. 768, there could be as many as 10,000 to 20,000 job shifts relative to 1980 levels. Compared to 1995 there could be as many as 40,000 to 50,000 job shifts.

28. The present regulatory climate seems to encourage the use of existing coal-burning plants far beyond their normal life expectancy. Should we be providing incentives to spur the retirement of these older plants and encourage the construction of new plants with more current emission control devices?

The life expectancy of existing coal-burning plants seems to be increasing. Utilities are finding that it is more cost-effective to refurbish existing units than to build new ones. We think that there are three major reasons for these trends:

- The high cost of capital compared to the period when existing plants were built.
- Public Utility Commission treatment of capital investments.
- Additional environmental controls required on new units.

It would be exceedingly difficult to determine the relative importance of these factors. However, it is clear that it would be extremely expensive to overcome these incentives for extending the lifetime of existing units. A new coalfired plant costs roughly $800/kw to build and NSPS pollution controls can add 5 to 20 percent to that cost. It is almost always cheaper to refurbish an existing plant and, if necessary, retrofit a scrubber or switch to lower sulfur coal, than to replace it.

29. When would the present Clean Air Act provisions achieve through plant retirements and other actions the same reductions in sulfur dioxide emissions that are being mandated by the Senate Environment and Public Works Committee?

The Senate Environment and Public Works Committee Bill (the 8 million ton reduction version) would reduce total Eastern SO_2 emissions to about 12 million tons from 1995 forward. If new plants were controlled even more tightly than the current NSPS, and existing plants retired after 40 years, then somewhere between 2010 and 2020 SO_2 emissions would decline to 12 million tons.

On the other hand, if NSPS regulations did not become more stringent, or if plant lifetimes were longer than 40 years, total SO_2 emissions would not decline to 12 million tons until well after 2030.

30. What progress has been made over the past decade in reducing sulfur dioxide emissions in the Northeast, Midwest, South and West?

Nationwide SO_2 emissions declined by roughly 20 percent during the period from 1973 to 1982. We are in the process of preparing a report describing state-by-state trends for the period 1970 to 1980. We will provide the Committee with a copy of the report by early August.

31. Don't several recent studies, including the National Academy of Sciences 1983 report and the Interagency Task Force's FY'82 report, suggest that local emissions from petroleum and coal combustion may contribute just as significantly to the occurrences of acid deposition as do emissions from long-range sources?

The NAS 1983 (Calvert Committee) Report concluded "the relative importance for deposition at specific sites of long-range transport from distant sources as compared with more direct influences of local sources cannot be determined from currently available data or reliably estimated using currently available models."

The ITF FY'82 report did mention as a program accomplishment a "completed preliminary study on emission sources that suggested that nearby petroleum combustion and local and distant coal combustion could significally affect local acid deposition."

APPENDIX D

Answers to Questions Submitted to The Honorable Donald Paul Hodel, Secretary, Department of Energy

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Richard

Department of Energy
Washington, D.C. 20585

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
JUN 15 1984

June 15, 1984

Mr. Richard Grundy
Committee on Energy
  and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Grundy:

On April 30, 1984, Secretary Hodel appeared before the Energy and Natural Resources Committee to discuss the implementation of the Acid Precipitation Act of 1980.

Following that hearing, written questions were submitted for our response to supplement the record. Enclosed are answers to those questions. Copies have been sent directly to the Chairman and the Committee printer.

If you have any questions, please call Cathy Carey or Tom Pretorius of my staff on 252-4277. They will be happy to assist you.

Sincerely,

Thomas H Pretorius
for Robert G. Rabben
Assistant General Counsel
for Legislation

Enclosure

cc: Mr. Al Astrin

POST-HEARING QUESTIONS AND ANSWERS

Relating to the

APRIL 30, 1984, HEARING

Before the

COMMITTEE ON ENERGY AND NATURAL RESOURCES

UNITED STATES SENATE

WITNESS: SECRETARY HODEL

Q1. What is the Department of Energy doing to develop new clean coal-burning technologies, including providing either federal research or federal assistance towards research for the commercialization of emerging sulfur dioxide control technologies? How much money is being spent on these efforts in the Department of Energy budget and how much is provided in the proposed federal acid precipitation research effort for FY 1985?

A. The Department of Energy has a strong research program in the development of coal combustion technologies designed to reduce the levels of sulfur dioxide and to significantly improve the cost-effectiveness of controlling acid rain precursors and enhance the marketability of high sulfur coal. These technologies include: Atmospheric Fluidized Bed Combustion (AFBC), Pressurized Fluidized Bed Combustion (PFBC), Advanced Combustors, Coal Preparation and Flue Gas Cleanup Systems.

In AFBC, we are an active participant with TVA in the construction of a 160 Mw demonstration facility. There are many other participants in the program, most from the private sector.

In PFBC, we are engaged with Great Britian and the Federal Republic of Germany in the IEA/Grimethorpe, England facility. Research is also being conducted at the New York University test rig and at the Coal Utilization Research Laboratory located in Leatherhead, England. Contracts with private industry have been awarded for research on two advanced combustor concepts.

We will begin a new initiative in FY 1985 to develop and test advanced physical coal cleaning systems which offer significantly improved sulfur and ash rejection and reduced BTU loss with improved economics.

A new initiative will also be started in FY 1985 in the flue gas cleanup area to develop a low cost, relatively modest performance system that is capable of being retrofitted to existing boilers. This initiative is specifically intended to respond to acid rain concerns related to existing coal fired units.

The FY 1984 funding and the FY 1985 budget request for acid rain related research follows:

	($ in thousands)	
	FY 1984	FY 1985
Coal Technology & Coal Preparation		
Flue Gas Cleanup	8,100	14,025
Gas Stream Cleanup	7,000	4,975
Waste Management	2,900	2,000
Coal Preparation	8,000	11,150
Subtotal	26,000	32,150
AR&TD		
Environmental Activities		
Acid Rain Task Force	260	750
Subtotal	260	750
Combustion Systems		
AFB Combustion	1,400	2,500
Paducah, KY AFB (TVA)		15,000
PFB Combustion	7,500	5,000
Adv. Combustion Tech.	1,700	2,000
Subtotal	10,600	24,500
TOTAL	36,860	57,400

Q2. If an acid rain control program is adopted now which requires scrubbers, what coal supply regions of the country would stand to lose markets due to coal switching? What energy losses would there be? How many coal mining jobs would be affected? What would the costs be? Please answer these questions as they pertain to the controls proposed by: (a) S. 768; (b) H.R. 3400; (c) H.R. 4404. If any studies have been done examining these issues, would you please submit them for the record.

A. Coal Markets

Each of these bills would reduce demand for high sulfur coal and stimulate use of low sulfur coal; but there are major differences. Given the freedom to choose the reduction technique, as would be the case with S. 768, the majority of affected plants would probably opt for increased coal switching due to lower cost and thereby produce more severe dislocations in coal markets and coal miner employment. These dislocations would take the form of reductions in high sulfur coal production in the East and Midwest, and corresponding increases in low sulfur coal production in the West and Central Appalachia. Since H.R. 3400 and H.R. 4404 both mandate that the 50 top sulfur emitting power plants install scrubbers, their impacts on coal market shifts would be much reduced as compared to proposals that allow fuel switching. For those 50 plants, the possibility of achieving SO2 emission reductions only by switching from high to low sulfur coal is precluded, and the required scrubber generally will provide the total emission reduction.

The recently-available ICF, Inc. analysis for EPA of H.R. 3400 1/ predicts that, by 1995 retrofit scrubbers under H.R. 3400 would be 67.5 GW, but given a cost-effective equivalent for the large emitters, retrofit scrubbers would only be 2.5 GW. This assumes a 1995 SO2 reduction requirement of 9.1 million tons assigned to utilities.

As noted in another analysis conducted by ICF for EPA, 2/ SO2 emission reductions on the order of 12 million tons per year (MTY) would often require both flue gas scrubbing and reduced sulfur content in coals for some states to meet the assigned level of emissions reduction. An assessment prepared by OTA 3/ focusing on a required SO2 reduction of 10 MTY estimated a higher sulfur coal use decrease of 17 million tons per year. The requirement for H.R. 4404 is 12 MTY SO2 reduction; using these aforementioned studies as bases, the DOE estimate for a pronounced reduction in high sulfur coal use is 25 MTY. Thus, the difference in coal use reduction between achieving the 10 million ton SO2 reduction requirement (H.R. 3400) and the 12 million ton SO2 requirement (H.R. 4404) could be as much as 50 percent.

The following high and low estimates represent a range of coal market impacts. The lower values represent OTA estimates of impacts. The higher estimates, DOE data references and estimates.

Proposed Legislation	High Sulfur Coal Reduction
10-12 MTY SO2 Reduction with scrubbing "Top 50" (H.R. 3400, 4404)	17-25 MTY
10-12 MTY SO2 Reduction without scrubbing "Top 50" (S. 768)	50-70 MTY

ICF, 4/ in a report prepared for EPA, estimated the following regional shifts in coal production in 1995 as a result of an 8- million ton SO2 reduction, with an emission cap, for options similar to S. 768.

Coal Region	Change from 1995 Base
Northern Appalachia	-72.3 million tons
Central Appalachia	+66.1 million tons
Midwest	-77.3 million tons
West	+81.1 million tons

The ICF report to EPA for H.R. 3400 5/ provides the following coal market shifts relative to the 1995 baseline of that report.

Coal Region	Change from 1995 Base
Northern Appalachia	-9 million tons
Central Appalachia	+4 million tons
Midwest	+5 million tons
West	+3 million tons

This relatively small shift can be compared to the much larger shifts ICF predicts for the cost-effective equivalent case in the same report.

Coal Region	Change from 1995 Base
Northern Appalachia	-56 million tons
Central Appalachia	+55 million tons
Midwest	-94 million tons
West	+97 million tons

Thus the very recent ICF report provides greater coal market impacts for the cost-effective option and for S. 768, and much reduced estimates for H.R. 3400, compared to the earlier OTA estimates.

Employment Impacts

As coal markets are impacted, so are coal industry employment dislocations. OTA estimated that for each 1 million ton reduction in coal production, 350 coal industry employees would not be employed.

Proposed Legislation	Employment Reductions/High Sulfur Coal Industry
SO2 Reduction with "Top 50" Scrubbing (H.R. 3400, 4404)	6,000-9,000
SO2 Reduction without "Top 50" Scrubbing (S. 768)	18,000-25,000

The ICF report for H.R. 3400 6/ suggests that the employment losses in high-sulfur coal mining employment in 1995 would be:

H.R. 3400	9,000
Cost effective equivalent	50,000

This is a greater than 5:1 ratio based on the ICF report.

On the other hand, ICF predicts aggregate coal mining employment would shift by only 1000 mining jobs between the two alternatives and be down 4,000-5,000 jobs from the expected level given the 1995 baseline. Coal transportation jobs, according to ICF, would increase 4,000 jobs from H.R. 3400 to the cost-effective alternative.

It is apparent from the figures above that the miner dislocation caused by mandated reductions without a "Top 50" type requirement range from three to five times the severity with the "Top 50" requirement. In addition to the direct employment impacts, there is a generally acknowledged multiplier effect for indirect loss of employment in a community, which could reach three times the number of coal industry dislocations.

Cost of Coal Switching

Costs of coal switching are associated primarily with three factors: (1) need for greater particulate controls, (2) modification of boiler and pulverizer, and (3) increased transportation costs and energy use.

The Electric Power Research Institute (EPRI) has estimated total capital cost requirements of $130/kw for switching to western coal, and $35/kw for switching to Central Appalachia coal, in 1983 dollars.7/

Refer to our response to Question 11 for our estimates on total national costs of the various legislative proposals.

Energy Impacts

There are two types of energy losses that would result from mandated emission rollbacks. The first is a derating of boilers which switch to lower sulfur coals, which have lower Btu and higher ash contents or which are harder, and therefore more difficult to pulverize. The capital cost that would be necessary to mitigate the need to derate the boilers is estimated at about 50% of the capital requirement for switching to western coal ($70/kw.), and 14% of the capital requirement for switching to Central Appalachia coal ($5/kw).8/

There are also energy penalties associated with operation of flue gas desulfurization (FGD) equipment, since scrubbers require electricity to operate pumps and fans, as well as steam to reheat the moisture laden flue gas to avoid condensation and to boost the flue gas rise in the atmosphere. It is expected that FGD equipment would derate the power plant's output capacity by 3-5%.9/

Another type of energy impact concerns the possibility of Canadian power imports. It is reasonable to assume that in either of the cases discussed above, many utilities could opt to meet their power needs by importing electricity from Canada and shutting down plants. Questions 12 and 13 provide further information in this area.

References to Q.2

1. "Analysis of the Waxman-Sikorski Sulfur Dioxide Emission Reduction Bill (H.R. 3400); ICF, Inc.; April 1984.

2. "Preliminary Forecasts of 4, 8 and 12 Million Ton Reduction Cases," ICF Inc., June 1983.

3. "An Analysis of the Sikorski/Waxman Acid Rain Control Proposal: H.R. 3400," Office of Technology Impacts Staff Memorandum, July 12, 1983.

4. "Analysis of a Senate Emissions Reduction Bill (S. 3041)," ICF Inc., February 1983.

5. See Reference 1.

6. Ibid.

7. Testimony of Kurt Yeager, EPRI, before Subcommitee on Energy Development and Applications, U.S. House Committee on Science and Technology, September 20, 1983.

8. Ibid.

9. Ibid.

Q3. How much scrubber capacity can be retrofitted in this country by 1990?

A. There is no absolute answer to this question. Regarding the capability of the scrubber installation industry to meet the demand, the Industrial Gas Cleaning Institute has testified that there is adequate capacity, overall, to supply acid rain control needs. Nevertheless, the magnitude of construction program under possible control scenarios suggests there may be labor or material shortages in specialized areas. Our concern regarding shortages is based on the fact that some of the proposed acid rain bills could more than double the rate of scrubber construction of the past decade. We note that the nation has installed 43,000 Mw of FGD since 1971. The Edison Electric Institute study of H.R. 3400 estimated 57,000-87,000 Mw of scrubbers would be required to meet the requirements of that bill. Additionally, new coal plants are required to install FGD. This presents additional demands on vendors, A&E's and supporting trades.

Most existing plants can be retrofitted with scrubbers at a cost. Many different situations exist at power plants which can cause large variations in both the cost to retrofit scrubbers and the cost to operate scrubbers. Factors such as size and age of the plant and inadequate space can make many retrofits prohibitively expensive.

Q4. What, if any, difficulties are there with backfitting the installation of flue gas cleaning facilities for sulfur dioxide removal at existing power plants? Have any studies been done on this subject? If so, would you please submit them for the record.

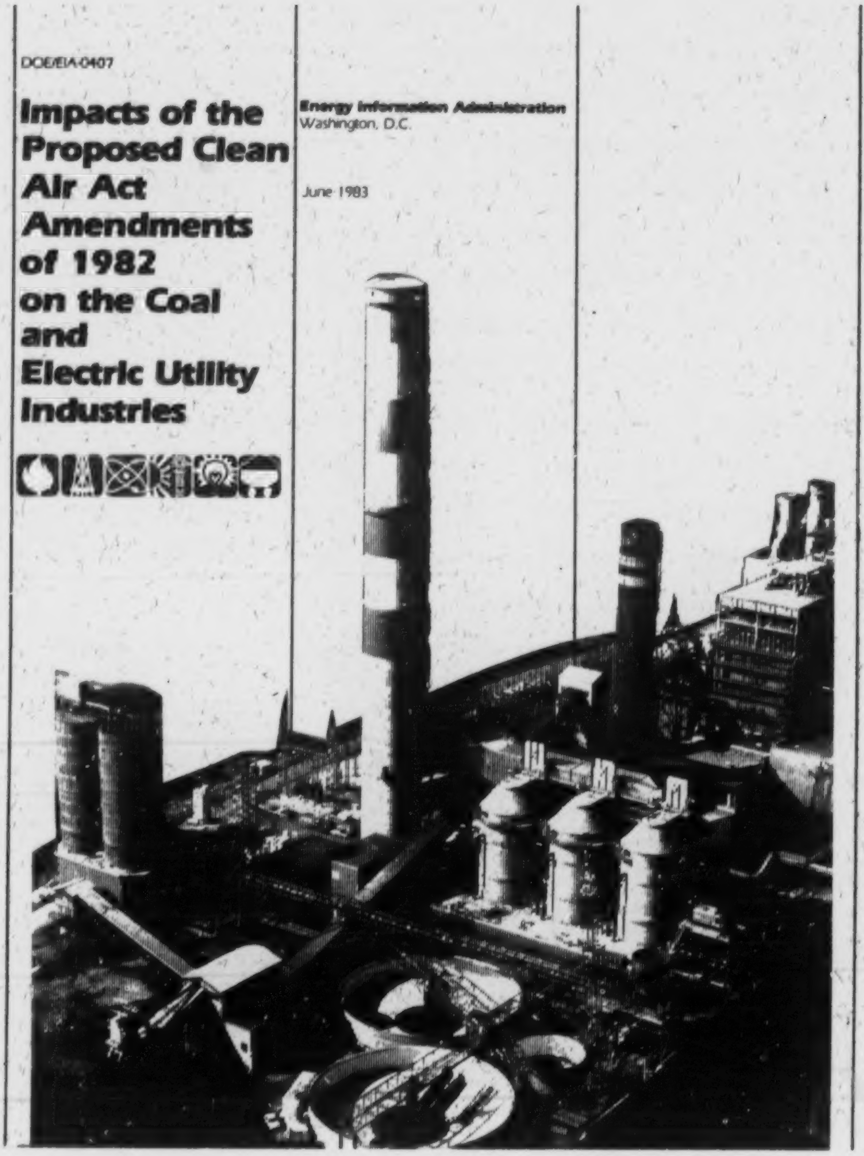
A. Major difficulties with backfitting include:

- Available space, both internal to the plant and external (limited land area).
- Building structure not capable of supporting the additional weight if roof top installation is considered.
- Existing inducted draft and forced draft fans cannot support the additional pressure drops required by the flue gas desulfurization system.
- Transportation limitations of both scrubbing reagents and waste products.
- Availability of additional waste disposal area to handle the large waste volumes generated by flue gas cleaning.
- Compatibility of existing plant control systems with the added new flue gas cleaning requirements.
- Loss of salable power which is required to operate the new systems.
- Skills to operate and maintain the new system.

We know of no published studies that address retrofit problems at existing plants in a comprehensive manner. The attached report Acid Rain: Control Strategies for Coal Fired Utility Boilers, funded by the Morgantown Energy Technology Center, which includes scrubber retrofit cost estimates developed by computer model, did address space limitations in a general fashion. This study addressed the cost of reducing emissions from the 50 highest emitting power plants. The attached report by the Energy Information Administration, Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries, also includes a premium for the cost of a retrofit scrubber versus a scrubber at a new plant. These cost estimates were also developed by computer model. Additionally, this report precluded scrubber application to certain units (totaling approximately 36,000 Mw) which were too old, small, or space constrained. A&E (Architect and Engineers) companies who are active in the power plant area undoubtedly have large files of this kind of information.

(Reports included in question 4.

1. "Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries", from the Energy Information Administration, Washington, D.C. (DOE/EIA-0407) June 1983.
2. "Acid Rain: Control Strategies for Coal-Fired Utility Boilers, Volume I", by M. Szabo, Y. Shah and J. Abraham, PEDCo Environmental, Inc., Cincinnati, Ohio. (This report was funded by the U.S. Department of Energy, Morgantown Energy Technology Center, Contract No. DE-AC21-81MC16361) May 1982.
3. "Acid Rain: Control Strategies for Coal-Fired Utility Boilers Volume II, Appendix", By PEDCo Environmental, Inc., Cincinnati, Ohio. (This report was funded by U.S. Department of Energy, Morgantown Energy Technology Center, Morgantown, WEst Virginia. Contract No. DE-AC21-81MC16361) May 1981. Full document is retained in the full Committee files.)



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Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries

Energy Information Administration
Washington, D.C.

June 1983

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DOE/EIA-0407

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Figure 4 on Page 19 was incomplete as printed. Please replace it with the attached page.

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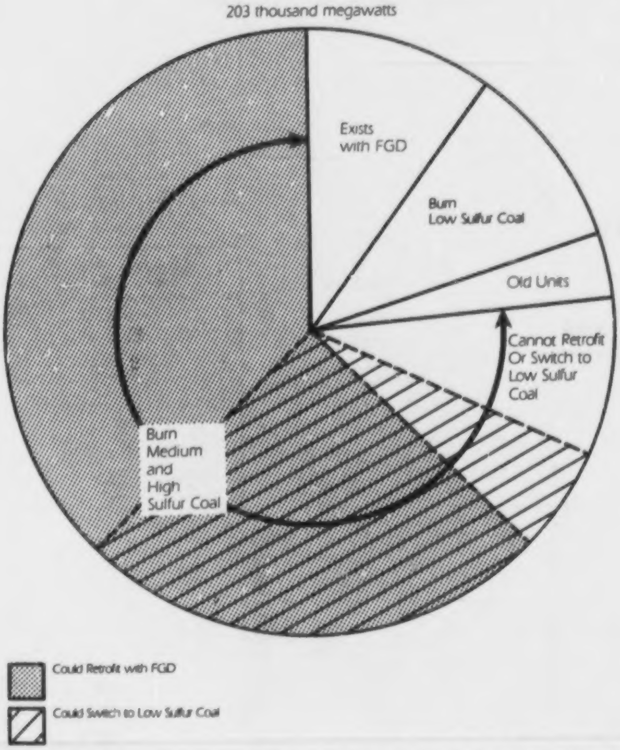
Figure 4. Coal-fired Capacity in 31 States (Existing as of 1/1/81)



Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, derived from the National Coal Model (NCM) and other sources, 1983

Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries

Energy Information Administration
Office of Coal, Nuclear, Electric and
Alternate Fuels
U.S. Department of Energy
Washington, D.C. 20585

DOE/EIA-0407
Dist. Category UC-98

June 1983

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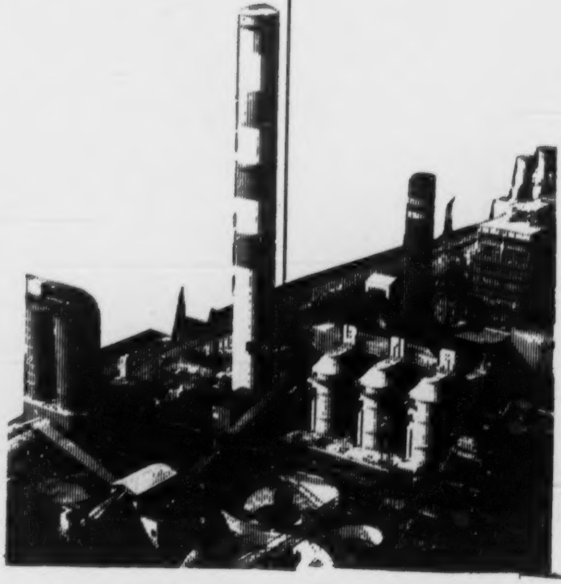
This report was prepared by the Energy Information Administration, the independent statistical and analytical agency within the Department of Energy. The information contained herein should not be construed as advocating or necessarily reflecting any policy position of the Department of Energy or any other organization.



PREFACE

The purpose of this analysis is to provide legislators, policymakers, analysts, and observers with an estimate of electric utility and consumer costs of reducing sulfur dioxide emissions, as proposed in Senate Bill S.3041, the Clean Air Act Amendments of 1982.

The analysis identifies the acid rain issue and the cutbacks in emissions mandated in S.3041. Through use of Energy Information Administration data and models, the study projects electric utilities' costs and electricity price increases in meeting the proposed requirements, assuming that the electric utility industry will take the least-cost option. It describes and quantifies the utilities' options in responding, which include shutting down and reducing the use of plants fired by high-sulfur coal, switching from high- to low-sulfur coal, and retrofitting plants with desulfurization equipment. Regional effects on coal production are examined, as are the effects of changed railroad rates for shipping coal.

The 1995 coal and electric power supply projections that appear in this report are based on the National Coal Model (NCM), a computer model of the coal and electric power industries. The NCM is not an integrated model and as such does not represent end-use demand sectors (e.g. commercial, industry) nor the non-coal fuel supply sectors (e.g., oil, natural gas). Domestic demands are taken from the 1981 Annual Report to Congress (ARC). These projections are based solely upon the aforementioned model and do not represent new integrative fuel forecasts for 1995, which the Energy Information Administration has not produced since the 1981 ARC was published.

This report was prepared by the Office of Coal, Nuclear, Electric and Alternate Fuels, Electric Power Division, Data Analysis and Forecasting Branch, Robert T. Eynon, Chief. The authors are Betsy O'Brien, Art Fuldner, Mary Paull, Tom Petersik and Suraj Kanhouwa. Jerry Price and Nathaniel Ng developed and applied the National Utility Financial Statement Model used in the report. The authors were assisted by the Coal Data Analysis and Forecasting Branch, especially William Orchard-Hays and Jim Watkins, in applications of the NCM. Questions regarding the report may be directed to the project director, Betsy O'Brien (202/252-9852).

This analysis has been prepared under the authority of Section 54 of the Federal Energy Administration Act.

To obtain additional copies, write or telephone the National Energy Information Center.

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202/252-8800

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EXECUTIVE SUMMARY

Senate bill S.3041, the "Clean Air Act Amendments of 1982," addresses the problem of acid deposition (acid rain) in the eastern United States. This legislation proposed reducing the sulfur dioxide (SO_2) emissions and limiting the nitrogen oxide (NO_x) emissions in a region that includes the 26 States east of the Mississippi River, and 5 States adjacent and to the west of the Mississippi, plus the District of Columbia, subsequently referred to as the 31 States. Under the proposal, by 1995 this region must lower annual SO_2 emissions to 8 million tons less than actual emissions in 1980, a reduction of approximately 50 percent of electric utility emissions in 1980. Increases in SO_2 emissions after January 1, 1981 must be offset by reductions from other sources.

Acid rain refers to the wet and dry deposition of acids--chiefly sulfuric and nitric acids--from the atmosphere to the earth's surface. Acid rain occurs after SO_2 and NO_x emissions combine in the atmosphere with other materials, in a chemical reaction. Thus the emission of SO_2 and NO_x is a precursory condition to the formation of acid rain. SO_2 and NO_x emissions into the atmosphere come from both natural and man-made sources.

This study determines the lowest cost means by which electric utilities can reduce their 1995 SO_2 emissions to comply with the legislation. Fundamental scientific and economic uncertainties surround the potential environmental benefits that would result from this level of reduction in SO_2 emissions. Therefore, a cost-benefit analysis of the proposed legislation is not currently possible.

This report is to help legislators, policymakers, and industry analysts to assess the costs of Senate bill S.3041--as well as costs of future similar legislation that may be proposed--to the electric utility industry and its consumers, and to assess its impact on the coal industry. Senate bill S.3041 did not pass the 97th Congress, but similar bills have been introduced in the 98th Congress, such as S.768. This report is unique in two respects:

- Every utility coal-fired boiler and electrostatic precipitator in the 31 States specified in the proposed amendment was examined to determine how the utility could reduce its SO_2 emissions. Limitations on the utility's options were taken into account, so that utilities' responses to the proposed amendment could be analyzed.

- Demand levels for electricity and transportation rates for shipping coal were varied in order to determine how such variations of these two important parameters would affect the projected results.

"Base case" in this study is actually a pair of base cases, both of which are examined for their effects on scenarios relating to the electric utility industry and to coal production. In one base case, S.3041 is assumed to be in effect; in the other base case, it is not.

Both base cases rest on the same two assumptions. The first assumption, drawn from the mid-case projections of EIA's 1981 Annual Report to Congress, is that the average annual growth in demand for electricity is 2.9 percent from 1980 through 1995. The second assumption, also based on EIA projections, is that transportation rates for coal will rise at a real average annual rate of 3 percent from 1983 through 1995.

It is assumed that decisions are made over a sufficiently long lead time to permit market structures to adjust in an orderly manner. For example, railroad facilities are assumed to be available when required, new western coal mines opened as needed, and long-term coal contracts (such as existing contracts with coal mines located near power plants) renegotiated when necessary. Mine-mouth power plants using high-sulfur coal are assumed to be able to switch to lower sulfur coal by 1995; however, captive coal mines associated with mine-mouth power plants in Ohio and Pennsylvania are projected to continue burning medium- and high-sulfur coal. These States include more than 82 percent of the total captive mine capacity included in this legislation.

The sensitivity cases examined the range of possible outcomes due to changes in two key assumptions. The growth in demand for electricity is varied to a high of 3.9 percent, and to a low of 1.9 percent. Growth in demand for electricity is studied because it affects the ability of a utility to retire plants that burn high-sulfur coal, or to use them less. It also affects the increase in SO_2 emissions from new sources that must be offset by existing plants.

Two variations of transportation rates are studied because of uncertainty about the additional increases required to obtain revenue adequacy for the railroads. Revenue adequacy refers to the ability of a railroad to earn enough profit to attract new capital. In one variation, the transportation rates increase 5 percent over the base case, compounded annually, and in the other, 9 percent compounded annually. Future rail rates for transporting coal affect demand for low-sulfur coal mined in the West.

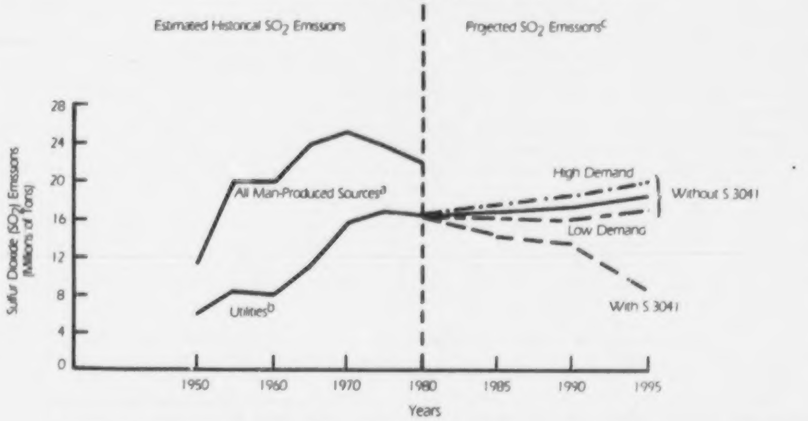
The report projects the amount of emissions from electric utility power plants that would occur by 1995 under the current limitations of the Clean Air Act. It also analyzes the effects of the proposed legislation on the electric utility industry, including the capital expenditures required to reduce SO_2 emissions, and the resulting effects on the cost of electricity. The initial 8-million-ton reduction in SO_2 emissions is assumed to be accomplished solely by electric utilities; industrial emission reductions are not considered. Similarly, only increases in SO_2 emissions from power plants are assumed to be offset by reductions within the utility industry; increases and offsets of industrial emissions are not addressed. Effects on the coal industry are also examined. The report concludes with a general discussion, based on current literature, of the potential benefits to be gained from reductions in SO_2 emissions. The benefits from the proposed legislation of an 8-million-ton reduction in SO_2 emissions and the value of such benefits are not specifically addressed.

The results developed in this study assume an economic response by electric utilities in meeting the requirements of the legislation. The analysis uses a modeling framework that minimizes the marginal cost of producing electricity on a regional basis, subject to the constraints of lower SO_2 emissions. Although uncertainties regarding some assumptions in this study have been analyzed, there are technical (e.g., railroad congestion), financial (e.g., cost of capital), and political (e.g., new legislation) considerations not addressed here. These considerations could lead to lower cost impacts or, more likely, higher costs than those reported. For example, if new legislation restricted utilities to the use of high-sulfur coal, then more retrofits with scrubbers would be required and costs would be higher.

Projections

Without the enactment of S.3041, SO_2 emissions from power plants are projected to increase for the 31 States from 16.1 million tons in 1980 to 18.1 million tons in 1995 (see Figure ES1). During the same period, NO_x emissions are projected to

Figure ES1. Electric Utility SO_2 Emissions in 31 States



[a] United States-Canada Memorandum of Intent on Transboundary Air Pollution, "Emissions, Costs and Engineering Assessment," United States/Canada Work Group on Emissions, Costs and Engineering Assessment, Work Group 3B, Final Report, June 1982, Table B.1.3, pp. 36-37.

[b] Pacific Environmental Services, Inc., Durham, N.C., estimated from electric utilities reports filed with the Energy Information Administration and the Federal Power Commission.

[c] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

increase from 4.8 million tons to 6.3 million tons. This increase will occur because new sources of emissions will be added more rapidly than old power plants are retired. The emission levels increase through 1995 even though the new coal-fired units produce much lower emissions as they generate electricity. Emissions from existing coal-fired units will decline continually as these units retire. The proposed legislation would accelerate this decline by requiring these units to reduce the 1980 SO_2 emissions level by 8 million tons in 1995 and to offset new emission sources. When these existing units are all retired, 30 to 50 years after 1995, emission levels will be approximately the same with this legislation or without it. A limitation of this study is the absence of quantitative results for the post-1995 period.

Electric utilities can reduce their SO_2 emissions from existing power plants by (1) retiring older units and/or reducing their use, (2) burning lower-sulfur coal, and (3) retrofitting existing power plants with flue gas desulfurization (FGD) systems. Each option has its own costs.

The impacts of S.3041 in the 31 States are summarized in Table ES1 for 1995. This table displays the projected values for each case with S.3041 minus those projected without S.3041 in order to determine the impacts of the proposed legislation. The increase projected in cumulative capital expenditures by 1995 is comprised of the costs to retrofit units with FGD systems, to modify some boilers or electrostatic

Table ES1. Differences in Expenditures and Capacity Modifications Projected with S.3041, Minus Those Projected Without S.3041, for the Base and Sensitivity Assumptions in 31 States, 1995

		Transportation Cost		Electricity Demand	
Impact of Legislation	Base[a]	5%[b]	9%[c]	Low[d]	High[e]
Financial					
Incremental Cumulative Capital Expenditures					
(Billion 1980 Dollars)	8.6	10.1	11.1	7.2	17.8
(Billion 1982 Dollars)	10.0	11.7	12.9	8.4	20.6
Incremental 1995 Annual Costs: Fuel, O&M					
(Billion 1980 Dollars)	2.6	4.1	4.6	0.6	6.7
(Billion 1982 Dollars)	3.0	4.8	5.3	0.7	7.8
Increase in 1995 Electricity Prices					
(1980 Mills per Kilowatthour)	2.7	3.0	3.0	0.9	3.7
(1982 Mills per Kilowatthour)	3.1	3.5	3.5	1.0	4.3
Incremental 1995 Revenue Requirements					
(Billion 1980 Dollars)	5.9	6.7	6.7	1.7	9.6
(Billion 1982 Dollars)	6.8	7.8	7.8	2.0	11.1
Operational					
Capacity Retrofitted with FGD					
(Gigawatts)	21.8	34.8	42.4	10.7	42.9
Capacity Converting to Low-Sulfur Coal					
(Gigawatts)	59.1	71.4	65.8	75.2	95.6

[a] The base case has a 2.9 percent average annual rate of growth in demand for electricity and approximately 3 percent average annual real increase in rail transportation costs. This column contains the difference in the base case with S.3041 minus the base case without S.3041.

[b] The 5-percent increase (compounded annually) in transportation costs is in addition to the 3 percent real increase in the base case. This column contains the difference in the 5-percent case with S.3041 minus the 5-percent case without S.3041.

[c] The 9-percent increase (compounded annually) in transportation costs is in addition to the base case transportation rate. This column contains the difference in the 9-percent case with S.3041 minus the 9-percent case without S.3041.

[d] Low demand is a 1-percent decrease (1.9 percent average annual growth rate from 1980 to 1995) in electricity demand growth. This column contains the difference in the low demand case with S.3041 minus the low demand case without S.3041.

[e] High demand is a 1-percent increase (3.9 percent average annual growth rate from 1980 to 1995) in electricity demand growth. This column contains the difference in the high demand case with S.3041 minus the high demand case without S.3041.

precipitators to burn low-sulfur coal, and to build additional power plants or transmission lines in order to retire older units or reduce their use. In the base case with S.3041, capital costs increase by $8.6 billion (1980 dollars). Of this total, FGD costs in 1995 are projected to be $2.8 billion (1980 dollars) higher than in the base case without the legislation; the cost to modify boilers or electrostatic precipitators is projected to increase by $2.1 billion (1980 dollars); and expenditures for new plants and transmission lines are projected to increase by $3.7 billion more than without S.3041 (1980 dollars).

In addition to increased capital expenditures, there would also be increases in the operation and maintenance expenses and fuel expenses for electric utilities in 1995. The expenditures for operation and maintenance are expected to increase by $335 million and for fuel by $2.3 billion (1980 dollars) if such legislation is implemented.

Increases in the price of electricity to consumers caused by the required reductions in SO_2 emissions are also projected. The price increases begin primarily after 1990 as significant capital expenditures are made, and in 1995 they are projected to be 2.7 mills per kilowatthour (1980 dollars) higher in real terms in the base case with S.3041 than without S.3041. This price increase is the result of an additional revenue requirement of $5.9 billion (1980 dollars; $6.8 billion in 1982 dollars) in 1995. This analysis assumes a time-phased plan for compliance with the legislation. The 1995 annual revenue requirement could be as high as $9.6 billion (1980 dollars; $11.1 billion in 1982 dollars), as shown in Table ES1. The results of this analysis fall within the range of those reported by other investigators. A detailed comparison with other studies is included in Chapter 7.

Findings

The changes proposed by the Clean Air Act Amendments of 1982 would result in a reduction of over 50 percent in the amount of SO_2 projected to be emitted by electric utilities in the 31 States in 1995. This represents only a 20-percent reduction in the 1980 natural and man-produced SO_2 and NO_x emissions, which are precursors of acid rain.[1]

Major findings of this report assessing the impacts of the proposed legislation using a least-cost approach are summarized below:

- Switching to low-sulfur coal is projected to be the preferred choice of electric utilities to reduce SO_2 emissions. Capital expenditures are not required for 60 percent of the boilers that convert to low-sulfur coal. However, if transportation rates for shipping coal increase substantially, utilities in the Midwest would likely continue using high-sulfur coal produced in their own or nearby States, and would retrofit more power plants with an FGD system.
- Cumulative capital expenditures in the 31 States affected by the proposed legislation are projected to increase by $7.2 billion to $17.8 billion, in 1980 dollars, for the range of scenarios considered. Most of this increase

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[1] Appendix B. Also, Jennifer A. Logan, "Nitrogen Oxides in the Troposphere: Global and Regional Budgets," Center for Earth and Planetary Physics (Harvard University, December 1982), Table 10. (Submitted for publication to Journal of Geophysical Research.)

occurs from 1991 through 1995 and represents 4.4 to 9.6 percent of projected total capital expenditures by all utilities in the 31 States for that period.

- Average electricity prices are projected to increase by 0.9 to 3.7 mills per kilowatthour across the various scenarios in 1995, as utilities must recover higher capital expenditures, fuel expenditures, and operating and maintenance costs. The 1982 average retail electricity price for privately owned utilities was 52.8 mills per kilowatthour in 1980 dollars.[2]

- The coal industry is likely to experience large shifts in the amount of coal produced in the different regions. In the Midwest, coal production is projected to drop below its 1980 level, and in Northern Appalachia and the Central West coal production is projected to grow at a slower rate than currently expected. Central Appalachia and the Western Northern Great Plains are projected to increase their production since the legislation benefits the producers of low-sulfur coal. The large shifts in regional coal production indicated in this study are likely to result in (1) a major redistribution in the employment of coal miners, and (2) shifts in regional economies as revenues from coal production in individual States are affected. No analysis has been made of the social costs of the shifts in coal production and their effects on employment of coal miners.

- Five States--Ohio, Missouri, Indiana, Pennsylvania, and Illinois--that account for 50 percent of the projected reduction in 1995 SO_2 emissions would have higher electric utility capital expenditures, higher electricity prices, and lower State coal production with this legislation. In the base case with the legislation minus the base case projected without it, the increases in capital expenditures for the five States range from $185 million to $1,037 million (in 1980 dollars). Electricity prices increase 1.2 to 3.3 mills per kilowatthour (in 1980 dollars) among the five States, and State coal production in 1995 would decline by 0.3 to 37 million tons.

Benefits from the proposed amendments include improvements in air quality. Additional environmental benefits may occur from improved water and wildlife, agriculture and forestry, greater longevity of man-made structures, and better human health. Because such benefits are as yet unproven, it cannot be determined if their value will be more than, less than, or equal to the total costs of reducing emissions.

As stated earlier, this analysis assumes a minimum-cost response by electric utilities for complying with the legislation. These projections are based on current laws and regulations, and as such they can be viewed as likely only if no future changes in laws or regulations occur. If additional coal mine safety laws are enacted in the future, or if restrictions are placed on electric utilities in their selection of options, the cost increases will likely be higher than those reported here.

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[2] Energy Information Administration, Office of Energy Markets and End Use, Monthly Energy Review, DOE/EIA-0035 (83/04) (Washington, D.C., April 1983), p. 92.

1. INTRODUCTION

Acid rain is one of the major environmental issues of the 1980's. Fourteen bills were submitted to the 97th Congress (seven in the House and seven in the Senate) for the purpose of controlling acid rain or related air quality problems. Proposals for controlling acid rain usually focus on the electric utility industry as a major source of emissions that result in acid rain. These precursory emissions are sulfur dioxide (SO_2) and nitrogen oxides (NO_x).

"Acid rain," more properly termed "acid deposition," refers to both the wet and dry depositing of acids from the atmosphere, predominantly acids of sulfur and nitrogen. The standard measure of acidity (pH) is a numeric scale falling from 14 (alkaline) to 0 (acid). Each one-unit drop in pH value indicates a tenfold increase in acidity. A pH of 7 is neutral. The complex chemical interactions in the atmosphere among sulfur and nitrogen and other elements (including ozone, carbon dioxide, volatile organic compounds, particulates, and metal catalysts), which produce acid deposition, are not well understood.

Sulfur and nitrogen emissions are both natural and man-produced. Worldwide, natural sulfur emissions from seaspray evaporation, organic decomposition, and volcanoes comprise about 60 percent of total emissions. In the eastern United States, however, only about 10 percent of total sulfur emissions are believed naturally produced.[1] Far less is known about nitrogen emissions, although it is estimated that between 5 and 25 percent of total nitrogen emissions in North America are produced naturally.[2]

Total 1980 man-produced emissions in the United States for SO_2 and NO_x were 26.6 and 21.3 million tons, respectively.[3] The distribution of these emissions by source is shown in Figure 1.

This report projects the amount of SO_2 that will be emitted by electric utility coal- and oil-fired boilers in 1995 under the limitations of the current Clean Air Act, and analyzes the impact of Senate bill S.3041, Clean Air Act Amendments of 1982, which calls for reducing SO_2 emissions from major stationary sources in the eastern United States. The report further analyzes the effects of the proposed amendments on the electric utility industry, including the added capital expenditures required to reduce SO_2 emissions and the resulting effects on the cost of electricity. It also examines how reducing SO_2 emissions by electric utilities affects the coal industry, including shifts in coal production to low-sulfur coal. Finally, the potential benefits from the reduction of SO_2 emissions are discussed.

In Chapter 2, a brief history of the Clean Air Act is presented, along with regulations for SO_2 emissions for electric utility coal-fired boilers. Provisions of

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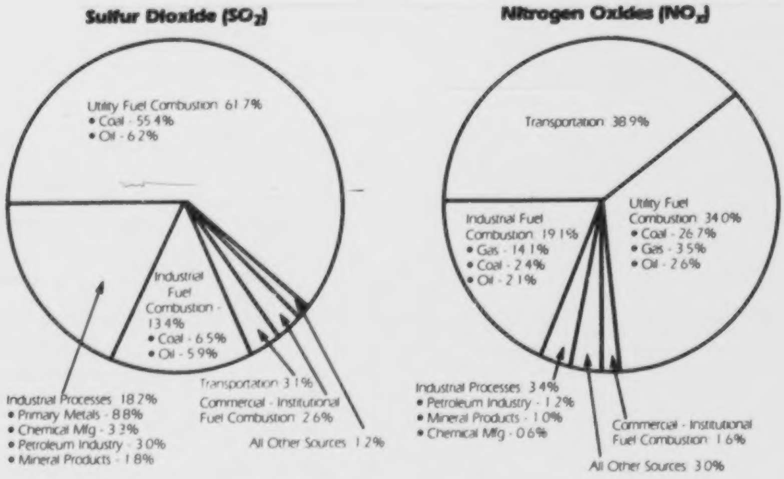
[1] GCA Corporation, Technology Division, "Acid Rain Information Handbook, Draft Final Report," (Bedford, Massachusetts, January 1983), pp. 2-10.

[2] Jennifer A. Logan, "Nitrogen Oxides in the Troposphere: Global and Regional Budgets," Center for Earth and Planetary Physics (Harvard University, December 1982), Table 10. (Submitted for publication to Journal of Geophysical Research.)

[3] United States-Canada Memorandum of Intent on Transboundary Air Pollution, "Emissions, Costs, and Engineering Assessment," United States/Canada Work Group on Emissions, Costs, and Engineering Assessments, Work Group 3B, Final Report (June 1982), Table B.2.1, p. 46 and Table B.2.3, p. 48.

Figure 1. U.S. Distribution of Sulfur Dioxide and Nitrogen Oxides - Man-Produced Emissions by Source, 1980



Sulfur Dioxide (SO_2) **Nitrogen Oxides (NO_x)**

Note: Minor Subtotals of Emissions Sources Are Not Shown

Source: GCA Corporation, Technology Division, "Acid Rain Information Handbook," Draft Final Report, (Bedford, Massachusetts, January 1983) pp 2-15, 2-16

Senate bill S.3041 regarding the proposed reduction in SO_2 emissions in the eastern United States by 1995 are described in detail.

The methodology for comparing the impact on SO_2 emissions by 1995 under provisions in the Clean Air Act with and without the proposed amendments is described in Chapter 3. The data assumptions and computer models used for analyzing SO_2 emissions in 1995 and determining the financial impacts on the electric utilities and electricity costs are described.

Chapter 4 presents an analysis of the impact on the electric utility industry of the proposed reductions in SO_2 emissions that would be required of utilities by 1995. The analysis considers additional capital requirements, ability of the utilities to raise capital, and the resulting changes in the cost of electricity.

Chapter 5 covers the impact of the proposed amendments on the coal industry, including possible changes in electric utility coal demand, and in the characteristics of coal that can be burned by utilities. Chapter 6 discusses potential benefits from reductions in emissions. Finally, Chapter 7 summarizes the findings.

2. THE PROPOSED 1982 AMENDMENTS TO THE CLEAN AIR ACT

This chapter gives a brief history of the Clean Air Act and describes its regulations for controlling sulfur dioxide (SO_2) emissions from coal-fired boilers of electric utilities. Additionally, the New Source Performance Standards and Revised New Source Performance Standards for SO_2 emissions from new and modified utility coal-fired boilers are discussed.

The 97th Congress of the United States considered the establishment of an acid rain control program. The proposal brought before the Senate called for amendments to the Clean Air Act that would reduce SO_2 emissions and limit nitrogen oxides (NO_x) emissions. The bill, S.3041, titled Clean Air Act Amendments of 1982, was reported out by the Senate Committee on Environment and Public Works. This chapter analyzes the provisions of bill S.3041 in detail; pertinent sections are summarized.

Clean Air Act

Although the Clean Air Act (CAA) was passed in 1963, it was not until 1970 that the Federal Government empowered the Environmental Protection Agency (EPA) to set uniform air quality standards. Under the Act, the EPA has set National Ambient Air Quality Standards (NAAQS) for ambient pollutant concentrations for seven of the most common and widespread pollutants: sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter, lead, carbon dioxide, hydrocarbons, and ozone. The CAA limits the amounts of SO_2, NO_x, and particulates that may be emitted by coal-fired boilers.

For enforcement purposes, the United States was divided into 274 air quality control regions. Each region has to meet the limits imposed by the NAAQS. Control regions within State boundaries where the ambient pollutant concentrations are below or meet the NAAQS are designated as "attainment areas." Areas where the ambient pollutant concentrations are above the NAAQS are designated as "nonattainment areas." In nonattainment areas, the States are required to devise a strategy to ensure that the minimum standards set by EPA are met and maintained. This strategy is incorporated into State Implementation Plans, or SIPS. New and modified pollution sources within nonattainment areas are required to achieve the "lowest achievable emission reduction" (LAER), regardless of cost.

In 1977, the CAA was amended to require that States set limits on the existing pollution sources within nonattainment areas. It was specified that such sources must use "reasonably available pollution control technologies" (RACT). Both technological and economic feasibility are considered when applying RACT to existing sources. In "attainment areas," new and modified pollution sources are regulated to "prevent significant deterioration" (PSD) of the clean air within the control region. These sources are required to use the "best available control technology" (BACT). BACT is an emission limitation based on the maximum degree of reduction that can be achieved when energy, environmental, and other costs are considered.

The 1971 New Source Performance Standards (NSPS) issued by EPA required that utility coal-fired boilers of 73-megawatt (MW) output or greater, on which construction or modification had begun after August 17, 1971, could not emit more than 1.2 pounds of SO_2 per million British thermal units (MMBtu) of heat input. Plant operators were required to use "continuous emission monitoring" to measure the SO_2 emission levels in the flue gas outlets of coal-fired boilers. If the average emission level exceeded the NSPS standard for more than 3 hours, the plant could be cited for violation.

In 1979, EPA issued Revised New Source Performance Standards (RNSPS). These standards are more stringent than NSPS and apply to all coal-fired utility plants capable of producing more than 73 MW of generating capacity, and on which construction or modification began after September 12, 1978.

The new standards retain the 1971 NSPS standard of 1.2 pounds SO_2 per MMBtu of heat input as a ceiling for emissions, but additionally require that SO_2 emissions from all new or modified (post-1978) boilers be reduced on a sliding scale of percentages that considers the different sulfur contents of U.S. coals. All coals burned must have at least 90 percent of the SO_2 removed from their emissions, unless 90-percent removal reduces emissions to less than 0.6 pounds per MMBtu. If emissions go below that level, reductions between 70 and 90 percent are permitted, depending on the sulfur content of the coal. Utilities are required to monitor SO_2 emissions continuously, both at the flue gas inlet and at the outlet of these new sources, to determine whether the required removal is attained on a 24-hour rolling average.

The RNSPS regulations require the use of some form of flue-gas desulfurization (FGD) unit, or "scrubber," for all new or modified utility boilers, since only scrubbers can reduce emissions by more than 70 percent.

Acid Rain Provisions in Senate Bill S.3041

Senate bill S.3041 was introduced on November 15, 1982, and amends Section 120 of the Clean Air Act by adding "Part E" to address the problem of acid deposition in the eastern United States. Part E establishes an acid deposition impact region consisting of 31 States and the District of Columbia: the 26 States east of the Mississippi River and 5 States contiguous to it on the west. Table 1 summarizes the contents of S.3041, Part E.

The bill requires that by January 1, 1995, the annual SO_2 emissions within the region must be 8 million tons less than the actual emissions during 1980. Increases in SO_2 emissions from major stationary sources after January 1, 1981, must be offset by reductions from other sources in the region by January 1, 1995. Two exceptions are allowed: (1) additional reductions will not be required when increased emissions are in a State that during 1980 had no utility boiler emitting at an annual rate greater than 1.2 pounds of SO_2 per MMBtu of heat input; and (2) if the increase results from converting a utility boiler so that it can burn coal, as specified by the Fuel Use Act of 1978 (P.L. 95-620), emissions must be reduced only to the extent that they exceed an annual average rate of 1.5 pounds per MMBtu.

Any major stationary source of SO_2 emissions that begins operation after January 1, 1995, must provide for simultaneous emissions reductions elsewhere in the region to offset its own emissions, unless it adopts the best available control technology (BACT) and meets the most stringent emission limitations achieved by any source of the same size, type, and class in the region. Emissions of nitrogen oxides (NO_x) from existing major stationary sources, except for boilers converted to coal use, may not increase over 1980 levels or over levels experienced during a 30-day period immediately prior to enactment, unless equivalent reductions are obtained elsewhere in the region.

The Governors of the 31 States in the impact region have 18 months from the date of enactment to review and negotiate an agreement to allocate the reduction requirements. If the Governors of 23 or more States agree to an allocation plan, the plan

Table 1. Summary of S.3041, the Senate Committee on Environment and Public Works

TITLE:	Adds Part E--"Interstate Transport and Acid Precursor Reduction" to Title I of the Clean Air Act.
IMPACT REGION:	26 States east of the Mississippi River, 5 States bordering the Mississippi River on the west, and the District of Columbia.
REGIONAL EMISSION INCREASE:	See SOURCE EMISSION INCREASE below. From 1/1/95, no SO_2 increase permitted; new sources meeting best-in-region BACT are exempt from offset requirements.
SOURCE EMISSION INCREASE:	No increase in actual SO_2 emissions as of 1/1/81, unless offset elsewhere in region; does not apply where the SIP limits all sources to 1.2 lb SO_2/MMBtu, or to emissions of 1.5 lb SO_2/MMBtu or less from boilers converted to coal use. No increase in actual NO_x emissions as of 1/1/81.
REDUCTION REQUIRED:	8 million tons/year SO_2 less than 1980 actual emissions.
SCHEDULE FOR REDUCTION:	By 1/1/93, conventional retrofit technology in operation; by 1/1/95, innovative technology or replacement facility in operation.
STATE SHARE OF REDUCTION:	Governors allowed 18 months to develop allocation plan; failing agreement, each State's share is equal to ratio of all its utilities' actual emissions in excess of 1.5 lb SO_2/MMBtu to region's total actual emissions in excess of 1.5 lb SO_2/MMBtu.
SOURCE OF REDUCTION:	Unspecified.
REDUCTION APPROACHES PERMITTED:	May be used if enforceable: (1) least-emissions dispatch, (2) early retirement, (3) quantifiable energy conservation investment, (4) regional trading, and (5) precombustion cleaning of fuels.
NO_x CREDITS:	Not permitted.
NONCOMPLYING SOURCES:	Major sources not in SIP compliance in 1981 must be in compliance by 12/31/85 or be subject to 1.2 lb SO_2/MMBtu emission limitation.
STUDIES REQUIRED:	(1) Additional funding for and reports from Interagency Task Force, (2) independent scientific review board established by the National Academy of Science, (3) EPA and Treasury study of possible utility fee systems to finance emissions reductions, and (4) EPA NO_x inventory and control technology study.

Table 1. Summary of S.3041, the Senate Committee on Environment and Public Works (continued)

REGULATORY AGENCY DEADLINES:	18 months from enactment: Gubernatorial allocation agreement. 42 months from enactment: SIP revision submittals or reductions. 6 months from submittal: EPA approval.
STATE DEFAULT:	Failure to reach gubernatorial agreement: see STATE SHARE OF REDUCTION above. Failure to submit or have approved SIP: 1.2 lb SO_2/MMBtu imposed on all utilities.

Source: Argonne National Laboratory, Energy and Environmental Systems Division, An Analysis of Proposed Legislation to Control Acid Rain, by D.G. Streets and others (Argonne, Illinois, 1983), pp. 9-10.

is binding on all States in the region. If the Governors fail to reach agreement, then each State's share of the 8-million-ton reduction is the ratio of total SO_2 emissions in excess of 1.5 pounds per MMBtu of heat input from each utility unit in the State, averaged over the calendar year 1980, to the total of such SO_2 emissions in all the States in the region over the same period. Any two or more States may agree to reallocate required reductions among themselves if the total reduction equals the total reduction required by the formula in those States.

Within 42 months after the date of enactment, that is, 2 years after an allocation plan has been agreed to by the Governors or imposed by the formula in the Act, each State is to have adopted and submitted to the EPA enforceable measures to achieve the required reductions. EPA will review the States' submissions, according to the State Implementation Plan, within 6 months. If a State fails to adopt appropriate measures that comply with requirements, then a limit on emissions of 1.2 pounds of SO_2 per MMBtu of heat input on a 30-day average will be imposed on all utilities in the State.

3. METHOD OF ANALYSIS

This report analyzes the projected operational and financial impacts on the electric utility and coal industries of the required 8-million-ton reduction in annual emissions of SO_2 proposed in the 1982 Senate Clean Air Act Amendments, S.3041. The proposed amendments also require that the rate of NO_x emissions not increase, except for generating units that convert from burning oil or natural gas to burning coal. For this analysis, no constraint was placed on NO_x emissions. NO_x emissions from existing units do not increase, but NO_x emissions from new sources were not offset with reductions from existing sources.

Forecasts of electricity generation and coal production through 1995 were developed with and without the requirement to reduce SO_2 emissions in 31 States. For the two cases, a comparison was made of the projected capital, operating and maintenance, and fuel expenditures of electric utilities; the price of electricity; and regional coal production, in order to assess the impacts of the legislation. The sensitivity of the results to the level of demand for electricity and the transportation costs for coal were also analyzed. Projections for the electric utility and coal industries were made with and without the legislation for each of the alternative assumptions.

The proposed legislation requires that in 1995 the SO_2 emissions from the 31 States be reduced 8 million tons from the 1980 annual emission levels. However, the exact 1980 emissions from each of the 31 States are not known; the flue gas at each power plant has not been measured. Instead, estimates have been made by the Office of Technology Assessment (OTA) from information reported to the Energy Information Administration on the sulfur content, quality, and quantity of coal delivered to each power plant. The proposed legislation also does not state how the 8-million-ton reduction should be accomplished. An allocation scheme is proposed in case the States affected cannot agree to a plan. This allocation scheme was used by the OTA to determine 1995 initial emission reductions, that is, the amount to be reduced before new sources are offset. Each State's fraction of the 8-million-ton reduction is the ratio of total emissions of SO_2 in excess of 1.5 pounds per million Btu from each utility unit in the State over the calendar year 1980, to the total of such emissions in all States in the region over the same period.

In this study, the upper bounds on the 1995 emissions are based on the OTA estimates of 1980 emissions as specified in the Committee on Environment and Public Works report on the Clean Air Act Amendments.[1] (See Table 2.) The upper bounds for electric utilities do not offset increases in SO_2 emissions from new industrial sources, only from new power plants. In addition, for this analysis each State is allowed to go above the upper limit by as much as 5 percent so long as the total emission limit for the 31 States is met. This feature represents some limited reallocation of reductions among States, which is an option in the proposed legislation. Also, since utilities are required to have a phased plan for emission reduction, it was assumed that one-fourth of the reduction would be accomplished by 1990.

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[1] Committee on Environment and Public Works, U.S. Senate, Clean Air Act Amendments of 1982, 97th Congress, Report No. 97-666 (Washington, D.C., November 1982).

Table 2. State SO_2 Emission Reductions
(Thousand Tons)

State	1960 Emissions	Initial Reduction
Alabama	543.1	208.5
Arkansas	26.5	0
Connecticut	32.0	0
Delaware	52.5	10.6
District of Columbia	4.6	0
Florida	725.9	246.5
Georgia	736.7	352.0
Illinois	1,125.6	654.6
Indiana	1,539.6	1,008.3
Iowa	231.3	107.7
Kentucky	1,007.5	585.1
Louisiana	24.8	0
Maine	16.3	1.4
Maryland	223.2	77.1
Massachusetts	275.6	66.3
Michigan	565.3	177.3
Minnesota	177.3	44.1
Mississippi	129.2	57.8
Missouri	1,140.5	774.8
New Hampshire	80.5	38.2
New Jersey	110.2	26.9
New York	480.3	160.9
North Carolina	435.4	17.7
Ohio	2,171.6	1,346.8
Pennsylvania	1,466.1	653.5
Rhode Island	5.2	0
South Carolina	213.1	63.7
Tennessee	933.7	552.8
Vermont	0.5	0
Virginia	163.7	6.4
West Virginia	944.2	469.1
Wisconsin	485.7	292.4

Source: Committee on Environment and Public Works, U.S. Senate, Clean Air Act Amendments of 1982, 97th Congress, Report No. 97-666 (Washington, D.C., November 1982).

Model Support

The projections contained in this report were prepared with two models, the National Coal Model (NCM)[2] and the National Utility Financial Statement Model (NUFS).[3] A detailed discussion of the input data for the NCM can be found in the data documentation report.[4] The NCM, a linear program, consists of three major components: coal supply, transportation, and coal demand. The coal supply component is represented in the model by 31 coal supply regions in the United States (see Appendix B) and 9 types of coal mines. The coal is also classified by quality into 30 types based on heat content and sulfur content.

Because each supply region is no larger than a State, the NCM accounts for State-specific mining laws, environmental standards, and taxation policies. The NCM estimates production from existing mines and determines when new mines are needed. Coal supply curves are the method the NCM uses to represent the economic decisions made by consumers. The transportation component assigns a cost for shipping coal from origin of supply to each demand region, and aggregates the 30 coal supply types to 19 demand types. Coal transportation costs are based on rail networks and unit train rates, and depend on the distance travelled, the terrain of the route, fuel costs, congestion, and competition.

The demand for electricity is fixed for all scenarios, but the quantity and quality of coal consumed to meet that demand is determined on a case-by-case basis. The demand for coal by sectors other than electric utilities is fixed for all scenarios. Electric utility demand for coal depends on the assumed level of demand for electricity, the amount of existing and new coal-fired capacity in each region, and the least-cost means of satisfying total demand for electricity.

The NCM simulates planning decisions for construction and operation of facilities that generate electricity. The projections of capacity expansion, power plant dispatch, types of coal selected, and fuel consumption are based on minimizing the marginal cost of producing electricity. The marginal cost includes the fuel cost and operating and maintenance cost, and for new power plants or modified power plants, a capital cost levelized over 30 years. The modifications include retrofitting a coal-fired unit with a flue gas desulfurization (FGD) system, or modifying a boiler to burn subbituminous instead of bituminous coal.

The electric utility power plants are classified by region into one of the following categories: existing coal-fired plants meeting one of three State Implementation Plan Standards (SIPS); new coal-fired plants meeting New Source Performance Standards or Revised New Source Performance Standards; nuclear power plants; oil- and gas-fired steam units; turbines; combined cycle units; and hydroelectric pondage and pumped storage power plants.

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[2] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Mathematical Structure and Computer Implementation of the National Coal Model, DOE/EIA/10/28-2 (Washington, D.C., 1982).

[3] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Utility Financial Statement Model (NUFS), Vols. I, II, and III (Washington, D.C., 1982).

[4] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Documentation of Data Inputs to the National Coal Model, DOE/EI/11857-1 (Washington, D.C., 1983).

Assumptions constraining the model include the amount of new generating capacity expected to be built, the amount of electric power that can be transferred between demand regions, and the allowed emissions of SO_2 from each plant type to comply with existing State or Federal standards by 1985. For scenarios that included the proposed legislation, an additional constraint was added to limit overall SO_2 emissions in each of the 31 States.

The NUFS model is a financial accounting system that uses the electric utility forecast from the NCM as a basis for projecting composite electric utility financial data summaries such as income statements, balance sheets, and other financial factors. Yearly expenditures on capital equipment, fuel costs, and operating and maintenance costs are produced for each of the 44 demand regions. This model also projects the average price of electricity for each region, based on construction and dispatch decisions forecast by the NCM, and on State Public Utility Commission rate-making practices.

Methods for Reducing Emissions

To meet the requirements of reducing SO_2 emissions, a standard level of cleaning of bituminous coal is assumed to occur. In addition, electric utilities have the following options in the model:

- Retire or reduce the use of power plants burning high-sulfur coal or oil.
- Change the type of coal the boiler burns to one with lower sulfur content.
- Retrofit the boiler with an FGD system.

However, not all options are available to each individual boiler because of physical limitations. For example, there may not be room on the unit for the massive FGD structure, or the unit may not be able to burn low-sulfur coal without modifications to the boiler or to the electrostatic precipitator. To analyze the response of the electric utilities to the proposed legislation these limitations were taken into account. For this study, each coal-fired boiler in the 31 States was studied and its ability to reduce SO_2 emissions was assessed (see Table 3).

The following three factors were used to determine if the boiler could retrofit with a FGD system:

- Size of the Unit--If the unit's capacity is less than 100 megawatts, it was considered too small to retrofit economically.
- Age of the Unit--If the boiler was built before 1950, its remaining life was too short to make FGD retrofit practical. This is a conservative constraint since these boilers are already 30 years old.
- Space--Physical constraints could make the retrofit too expensive, or impossible regardless of cost. The assessment of space constraints was based primarily on visits to the sites.

Table 3. Upper Bounds on Capacities of Electric Utility Coal-Fired Boilers Surveyed (Megawatts)

Region	Retrofit With FGD[a]	Convert to Low-Sulfur Coal[b]
Maine/Vermont/NH	337.0	30.0
Mass/Conn/Rhode Island	144.0	2,028.0
New York/New Jersey	2,153.0	5,355.0
Pennsylvania	10,902.0	6,985.0
Maryland, Delaware	1,527.0	2,708.0
Virginia/D.C.	2,243.0	3,004.0
West Virginia	11,311.0	9,835.0
N. & S. Carolina	8,552.0	13,727.0
Georgia	9,328.6	1,737.4
Florida	2,658.0	596.0
Kentucky	5,164.0	4,986.0
Tennessee	9,190.0	7,499.0
Alabama/Mississippi	8,960.2	7,472.6
Ohio	14,688.0	7,214.0
Michigan	7,808.0	2,697.9
Illinois	12,309.0	7,212.0
Indiana	10,377.0	2,263.0
Wisconsin	3,008.5	1,846.0
Minnesota	670.0	4,478.0
Arkansas/Louisiana	528.0	0.0
Iowa	3,200.6	3,125.1
Missouri	5,412.0	4,912.0
31 States plus D.C. Total	130,470.9	99,711.0

[a] This column represents an upper bound on the amount of generating capacity in each region that could retrofit with FGD.

[b] This column represents an upper bound on the amount of generating capacity in each region that could burn low-sulfur coal without modifying the boiler or electrostatic precipitator.

Source: Derived from PEDCo Environmental, Inc., Acid Rain Boiler Population Retrofit Analysis, Contract No. DE-AC01-82 EP12067, prepared for the U.S. Department of Energy (Arlington, Texas, 1983).

Limits were then placed on the amount of capacity in each State that could retrofit. These limits were represented as constraints in the linear program. The cost of retrofits ranges from $125 to $160 per kilowatt in 1980 dollars.

The ability of a boiler to burn low-sulfur coal depends on the type of firing. Cyclone boilers and Riley turbo units have ash-fusion temperature requirements that are obtained primarily with high-sulfur coals. Any boiler with such equipment usually could not burn coal containing less than 1.5 to 2 percent sulfur by weight.[5]

If the lower-sulfur coal also has different heat content characteristics, i.e., subbituminous instead of bituminous coal, the capacity of the power plant using it could be derated. A capital expenditure of $70 per kilowatt to modify the boiler is assumed for the NCM (1980 dollars).

Another limitation to the use of lower-sulfur coal is the impact on the performance of the electrostatic precipitator. The sulfur content does affect the efficiency of a cold electrostatic precipitator but has no significant impact on performance of a fabric filter or hot electrostatic precipitator. Any unit using a cold electrostatic precipitator could shift to low-sulfur coal by modifying the precipitator, at a cost of approximately $50 per kilowatt (1980 dollars).

Sensitivities

Projections of the cost of reducing SO_2 emissions and shifts in coal production are based on underlying assumptions about the future. A range of uncertainty exists in these assumptions. For this report, the impact on projections of changes in two key assumptions were studied: the level of demand for electricity and coal transportation rates.

The growth in electricity demand is important to this analysis because it affects the ability of a utility to retire plants burning oil and high-sulfur coals or to use them less. It also changes the amount of emissions from new sources that must be offset by reductions from existing units.

Yearly growth in demand for electricity, even since the 1973 oil embargo, has varied widely from 6.3 percent for 1975 to 1976, to minus 2.3 percent for 1981 to 1982.[6] Uncertainty about future growth of the economy and changing industrial use of electricity would affect the demand for electricity expected in the future. For this study, the base case has an average annual growth rate of 2.9 percent from 1980 through 1995. To capture the impact of a different growth in electricity demand, average annual growth rates of 1.0 percent less (1.9) and 1.0 percent more (3.9) were also studied.

Another area of uncertainty is the future rail rates for transporting coal. Additional increases in coal freight rates could be required to obtain revenue adequacy for the railroads. Revenue adequacy refers to the ability of a railroad to earn enough profit to attract new capital. Higher transportation costs will result in an increase in the delivered cost of domestic coal and shifts in the location of coal production. Since much of the low-sulfur coal is mined in the West, the increased transportation costs could make investment in FGD equipment economical when local coals with higher sulfur content are available. Two cases were studied in which rates were approximately 5 percent and 9 percent, compounded annually, over the base case.

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[5] Some of these boilers, such as the Kammer plant in West Virginia, have been modified, at an approximate cost of $50 per kilowatt (1980 dollars), to burn lower-sulfur coal by using limestone injection.

[6] Energy Information Administration, Office of Energy Markets and End Use, Monthly Energy Review, DOE/EIA-0035 (83/03) (Washington, D.C., March 1983), p. 74.

The impacts on the electric utility and coal industries are discussed in the following chapters.

4. IMPACT OF PROPOSED AMENDMENTS ON THE ELECTRIC UTILITY INDUSTRY

Air quality regulations have affected the electric utility industry since the early 1970's. Through the Clean Air Act Amendments of 1970 and 1977, the SO_2 emissions allowed from new power plants have been tightly controlled. The New Source Performance Standards (NSPS) established by the Environmental Protection Agency (EPA) in 1971 for the implementation of the Clean Air Act Amendments require all new units to use low-sulfur coal or equip the unit with a flue gas desulfurization (FGD) system. In the 1979 revisions, new units no longer have the option to use low-sulfur coal. Instead all new units must be built with FGD equipment and 70 to 90 percent of the sulfur dioxide--depending on the coal's sulfur content--must be removed. The provisions of the proposed Clean Air Act Amendments of 1982 would also require existing power plants to have more stringent controls.

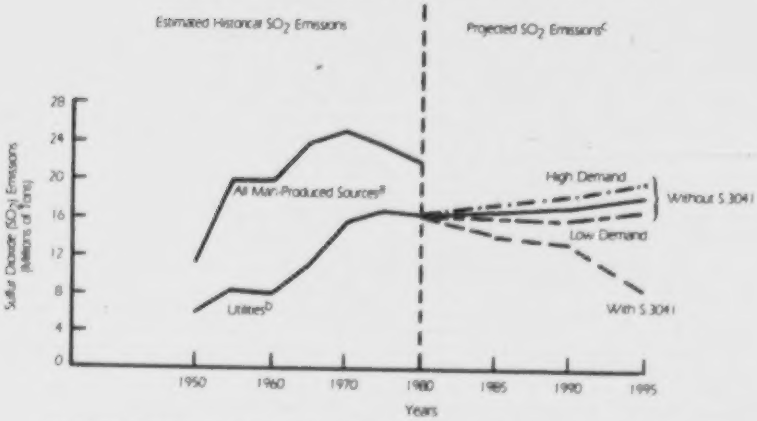
As shown in Figure 2, major increases in SO_2 emissions from electric utilities occurred from 1960 to 1970 with the increased combustion of fossil fuels. Since the late 1960's, SO_2 emissions from utilities have accounted for more than half of total man-produced emissions. Fuel combustion by residential, commercial, and industrial stationary sources, and industrial processes such as smelting, produce most of the additional SO_2 emissions. Between 1970 and 1980, utility emissions have increased only slightly, even with increased use of coal, because fuels with lower sulfur content have been burned and some FGD equipment has been installed.

Without the enactment and implementation of this proposed legislation, S.3041, SO_2 emissions from utilities are projected to increase in 1995 above the 16.1 million tons emitted in 1980. New sources of SO_2 emissions are arising faster than old power plants are being retired. Therefore the emission levels are projected to increase through 1995 even though the new coal-fired units produce much lower emissions. The growth in demand for electricity and amount of new capacity (coal-fired, nuclear, and hydroelectric) scheduled to begin operation by 1995 influence the rate of retirement of power plants and the level of emissions. SO_2 emissions for the 31 States specified by S.3041 are projected to range from 16.7 to 19.4 million tons in 1995. The low and high ranges are based on different assumptions about the average annual rate of growth in electricity demand, from 1.9 to 3.9 percent per year from 1980 through 1995. For all scenarios, the existing power plants are assumed to be in compliance with State Implementation Plan Standards (SIPS) by 1985.

In future years, the emissions from existing coal-fired units will decline even without additional legislation as the existing units (regulated by State standards that allow higher emission levels) are retired. They would be replaced by nuclear units or coal-fired power plants emitting no more than 1.2 pounds of SO_2 per million Btu (MMBtu) of input fuel.

Figure 3 illustrates the decline in projected SO_2 emissions from existing plants assuming a 40-, 50-, or 60-year life for coal-fired power plants. The proposed legislation accelerates the decline by requiring these units to reduce SO_2 emissions by 8 million tons in 1995 and to offset new emission sources. This reduction of over 50 percent in the SO_2 projected to be emitted by electric utilities in 1995 represents only 20 percent of the natural and man-produced SO_2 and NO_x emitted in the 31 States in 1980. (See Appendix B.) The projected SO_2 emissions in 1995 would be reduced by almost 60 percent in each of the States of Tennessee, Ohio, Illinois, Indiana, Wisconsin, and Missouri. Only Connecticut, Louisiana, Rhode Island, and the District of Columbia do not have to offset emissions from new sources because those States had implementation plans in effect limiting utility boiler emissions to 1.2 pounds of SO_2 per MMBtu or less.

Figure 2. Electric Utility SO_2 Emissions in 31 States



[a] United States-Canada Memorandum of Intent on Transboundary Air Pollution, "Emissions, Costs and Engineering Assessment," United States/Canada Work Group on Emissions, Costs and Engineering Assessment, Work Group 3B, Final Report, June 1982, Table B.1.3, pp. 36-37.

[b] Pacific Environmental Services, Inc., Durham, N.C., estimated from electric utilities reports filed with the Energy Information Administration and the Federal Power Commission.

[c] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

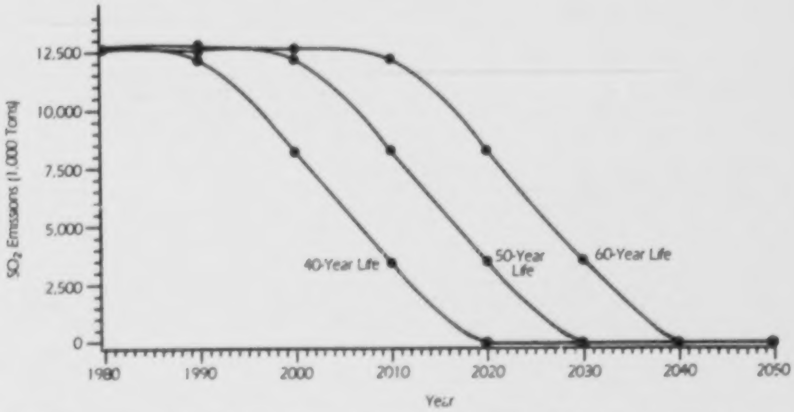
Emissions from generating units that convert from burning oil to burning coal also do not have to be offset, as long as the emissions from the coal-fired unit are less than 1.5 pounds of SO_2 per MMBtu. In this analysis, approximately 8,000 megawatts (MW) of capacity convert from oil to coal. These units are located primarily in the Northeast and the South Atlantic regions. Limits were not placed on NO_x emissions in this analysis. NO_x emissions from existing sources do not increase; however, emissions from new sources are not offset. An increase in total NO_x emissions of approximately 25 percent does occur from 1985 to 1995. Detailed tables of the SO_2 and NO_x emissions by region are contained in Appendix A.

This chapter discusses how the electric utility industry could achieve the reduction in SO_2 emissions and how that reduction would affect the financial status of the industry. Changes in the average price of electricity are also discussed.

Reduction of SO_2 Emissions

Electric utilities can reduce their SO_2 emissions from existing power plants by (1) retiring older units or using them less, (2) burning lower-sulfur coal, and (3) retrofitting existing units with an FGD system. Another process that was not included in this analysis but is being researched by EPA is the limestone injection/multistage burner (LIMB) process.

Figure 3. SO_2 Emissions From Existing Coal Plants, Assuming 40-, 50- or 60-Year Life



Source: Office of Environmental Protection, Safety, and Emergency Preparedness, U.S. Department of Energy, Electric Utility Unit Inventory Database

The House Subcommittee on Health plans to develop legislation in 1983 for a Clean Air Act Amendment that would use this LIMB technology.[1] The LIMB process is for pulverized coal boilers and would remove SO_2 and NO_x from the flue gases. The process combines low-temperature combustion techniques with injection of dry limestone into the combustion chamber. A development program is being studied by EPA for retrofitting units. Researchers are striving for 50- to 70-percent removal of the SO_2 at about one-fifth the capital investment cost of conventional FGD systems, which remove up to 90 percent of the SO_2. If developed, this process could be an economically attractive alternative to switching to low-sulfur coal. However, the overall reductions in State emissions that could result have not been calculated.

To determine the choices electric utilities would make to meet the reduced emission levels, several different scenarios were studied. The differences in the scenarios are either the rate of growth in electricity demand or the transportation cost of coal.

The base case has a U.S. average annual growth rate for electricity demand of 2.9 percent per year from 1980 through 1995. This rate of growth varies by region and was based on the EIA 1981 Annual Report to Congress. The low and high demand sensitivity cases have a plus-or-minus 1-percent difference in the growth rate.

The transportation scenarios both have higher expected rates. The cases assume a 5-percent and 9-percent real increase in transportation costs, compounded annually, above the base case from 1984 through 1995. In each of the transportation cases, the rate of growth in demand for electricity remains fixed at 2.9 percent. In addition, coal demand for sectors other than utilities is assumed to be fixed.

In the 31 States affected by the proposed legislation, approximately 203,000 MW of coal-fired capacity and slightly more than 60,000 MW of oil-fired steam capacity existed as of January 1, 1981. Currently, 76 percent of the coal capacity is burning medium- and high-sulfur coal. Not all of those units are physically able to retrofit with an FGD system. Figure 4 shows the amount of capacity that could make that choice. Similar problems exist with switching to low-sulfur coal. The figure also indicates the boilers that could use low-sulfur coal without modification.

In all the scenarios that assume enactment of S.3041, switching to low-sulfur coal is projected to be the preferred choice of electric utilities. Table 4 gives the increase in the amount of existing capacity as of January 1, 1981, that is projected to be modified by 1995.

For almost 60 percent of the capacity that converts to low-sulfur coal, no capital expenditure is required to modify the boiler or the electrostatic precipitator. For such units, the increase in fuel expenditures per kilowatthour (kWh) produced is much less than the comparable cost of retrofitting units with FGD equipment and burning higher sulfur coal. Even when the boiler or electrostatic precipitator must be modified, the capital expenditure is approximately one-third the cost of the FGD system.

The existence of long-term coal contracts, however, could be a problem for utilities. In 1979 through 1982, over 85 percent of the coal receipts reported by electric

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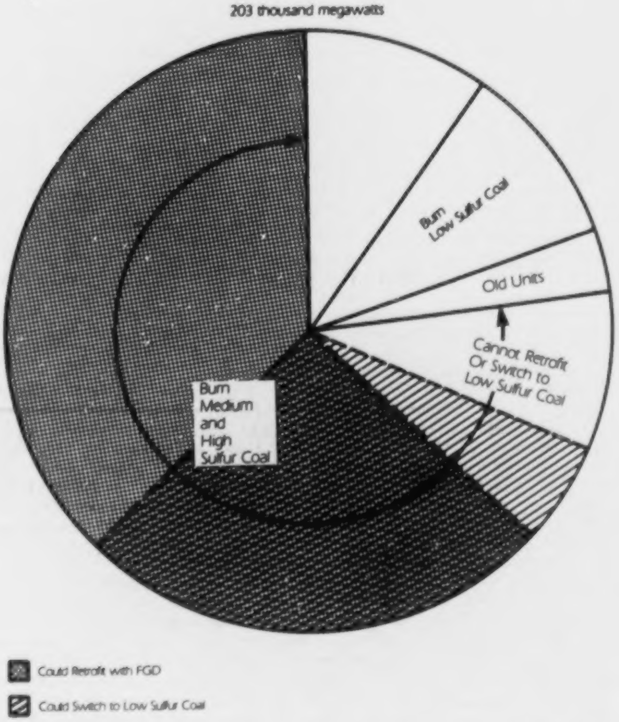
[1] "Waxman Wants High-Sulfur Acid Rain Alliance," Coal Outlook (March 21, 1982), p. 5.

Figure 4. Coal-fired Capacity in 31 States
(Existing as of 1/1/81)



Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, derived from the National Coal Model (NCM) and other sources, 1983.

Table 4. Capacity Modifications Projected With S.3041 Minus Those Projected Without S.3041 for the Base and Sensitivity Assumptions in 31 States, 1995[a] (Thousand Megawatts)

		Transportation Cost[b]		Electricity Demand	
Option	Base	5%	9%	Low	High
Retire Units					
Coal-fired	1.1	1.0	2.3	0.2	0.9
Oil-fired	17.7	17.7	17.9	8.7	21.4
Retrofit with FGD	21.8	34.8	42.4	10.7	42.9
Switch to Low-Sulfur Coal	99.1	71.4	65.8	75.2	95.6

[a] This table contains the differences in the projected values for each case with S.3041 minus those projected without S.3041 in order to isolate the impacts of the proposed legislation.

[b] Compounded annually.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

utilities were under such contracts.[2] Without the enactment of S.3041, the consumption of high-sulfur coal in the entire United States is projected to decline at most 8 to 16 percent from the 1980 consumption as new plants meeting NSPS by burning low-sulfur coal begin to operate, and older units are used less, or retired (see Figure 5). However, with S.3041 the projected reduction in the use of high-sulfur coal ranges from 38 to 76 percent. For present contracts that are not renegotiated or do not expire by 1995, financial penalties might have to be paid by the utilities. Also, some utilities have power plants sited near medium- and high-sulfur coal supplies. These units are referred to as mine-mouth plants. In the 31 States named in the legislation, approximately 42,000 MW of capacity operating as of June 1979 were classified as mine-mouth plants.[3] Approximately 2,000 MW of this capacity currently are equipped with a FGD system. About 11,500 MW of mine-mouth capacity receives all or part of the coal consumed from captive mines, that is, mines owned by the electric utilities. It is unlikely that any of these plants would switch to a lower-sulfur coal; instead they would have to retrofit some or all of these units with FGD equipment. Since this was not explicitly accounted for in the analysis, the amount of capacity projected to retrofit with scrubbers could be understated. In Ohio and Pennsylvania, approximately 10,000 MW of capacity is supplied by captive mines. In the analysis for these States, about 10,000 MW are projected to burn medium- or high-sulfur coal. About one-half of these plants are projected to retrofit with scrubbers. The remaining mine-mouth capacity (about 15,000 MW) in Ohio and Pennsylvania, which is not associated with captive mines, is projected to convert to low-sulfur coal. This result assumes sufficient time for these shifts to occur in an

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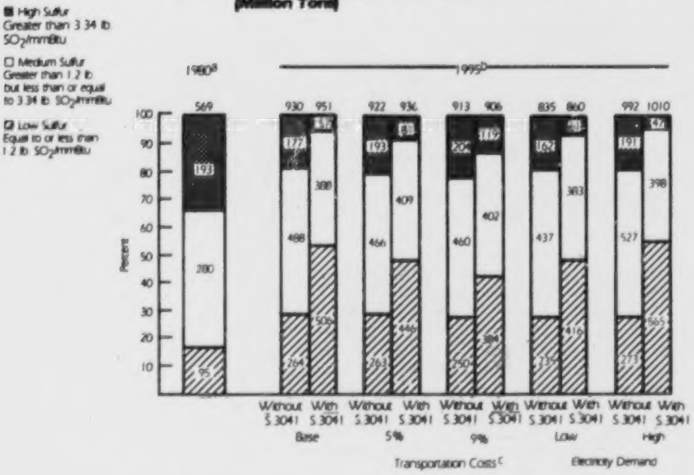
[2] Energy Information Administration, U.S. Department of Energy, Cost and Quality of Fuels for Electric Utility Plants 1981 Annual, DOE/EIA-0191 (81) (Washington, D.C., September 1982), p. 9.

[3] Federal Energy Regulatory Commission, Electric Utilities Captive Coal Operations (Washington, D.C.), June 1979.

Figure 5. U.S. Electric Utility Coal Consumption, 1980 and 1995 (Million Tons)



[a] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Form EIA-767, "Steam Electric Plant Air and Water Quality Control Data," 1980.

[b] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

[c] Compounded Annually.

orderly manner. If this capacity cannot switch to low-sulfur coal, then an additional $2 billion (1980 dollars) in investment would be required in these two States.

The switch to low-sulfur coal is less economical when the transportation costs for coal are higher. Electric utilities in States such as Ohio, Illinois, Kentucky, and Missouri are projected to use more coal produced in their own or nearby States and retrofit their power plants with FGD in both transportation cases. Coals with higher heat content per ton (i.e., bituminous coals) are also more in demand because shipping charges are based on the tons shipped. In the case of the 200-percent increase in transportation cost, Pennsylvania, Georgia, Tennessee, Alabama, and Mississippi would also retrofit more power plants with FGD. The increase in the amount of capacity projected to retrofit by 1995 in the base case with S.3041 versus without the proposed legislation would rise from about 22,000 to 35,000 MW in the 5-percent compounded increase in transportation costs, and to more than 42,000 MW in the 200-percent increase case.

Low and high demand affect the amount of new emissions that must be offset by existing sources. When higher demand is assumed, more units would be retrofitted or retired. Table 5 shows the amount of capacity additions projected for all the cases. In the high demand case with S.3041, an additional 9000 MW of new coal-fired units over the base case with S.3041 must be constructed to satisfy the higher demand for electricity, and their SO_2 emissions offset. The large additions to turbine capacity projected in the high demand case with and without the legislation indicate that electric utilities would have difficulty satisfying such a high rate of growth in demand over an extensive time horizon. Current utility plans for capacity expansion during the next 10 years are based on a lower expected growth in demand, 3.2 percent average annual growth rate from 1981 to 1991.[4] Slightly less switching to low-sulfur coal is projected than in the base case with S.3041 because a greater reduction in SO_2 emissions can be accomplished by retrofitting with FGD. In the low demand case, SO_2 emissions from new sources are projected to be 20 percent less than the base case with S.3041 in 1995. The use of low-sulfur coals and the retrofits with FGD systems are therefore less. Fewer new plants are projected to be built in the 31 States when demand for electricity is lower, so existing units are used more to satisfy baseload demand.

Retrofitting boilers with FGD systems to control SO_2 emissions was not projected to be an economical alternative unless the rail rates for delivering coal increase significantly. In addition to the capital expenditure, the operation and maintenance costs increase and the efficiency of the unit declines. The effect of requiring increased capacity to be modified with FGD systems on the reliability of electric utility systems is another important issue that was not specifically addressed. The past experience of the electric utilities with FGD equipment has been difficult. The equipment's reliability has been low; severe corrosion problems and the blocking of gas passages with solid deposits have been typical experiences. In addition, the utilities had little experience with chemical processes. The FGD process consists of mixing lime or limestone with water, then spraying the mixture into the flue gas. The SO_2 in the flue gas reacts with the mixture, forming calcium sulfite and/or calcium sulfate precipitate. Running and maintaining this equipment required additional staff with new skills. Extensive research has been carried out on corrosion-resistant alloys for FGD systems to reduce these problems.

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[4] North American Electric Reliability Council, Electric Power Supply and Demand, 1982-1991, (Princeton, New Jersey, August 1982).

Table 5. Existing and Projected Generating Capacity in 31 States
(Thousands of Megawatts)

		Projected Additions, January 1, 1981, Through January 1, 1995									
				Transportation Cost[c]				Electricity Demand			
	Existing as of January 1, 1981	Base Case		5%		9%		Low		High	
Type		Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041
Fossil-Fired Steam											
Oil	62	0	0	0	0	0	0	0	0	0	0
Gas	20	0	0	0	0	0	0	0	0	0	0
Coal	203	84	86	84	86	84	85	61	67	95	95
Nuclear	47	54	54	54	54	54	54	54	54	54	54
Other[a]	70	34	36	34	37	34	37	17	15	89	111
Total[b]	403	172	177	172	177	172	176	132	136	230	260

[a] Other includes hydroelectric generating units, turbines, and combine cycle units.
[b] Totals may not equal sum of components due to independent rounding.
[c] Compounded annually.
Source: Energy Information Administration, U.S. Department of Energy, National Coal Model (NCM), 1983.

A comparison was made of two cases with S.3041 to analyze the effects of higher costs of retrofitting coal-fired units with FGD systems. If the costs are assumed to be $190 (1980 dollars) instead of $160 for 90 percent removal of SO_2, the amount of capacity projected to retrofit would be 13,000 MW less. Instead, that capacity would switch to low-sulfur coal. The following States would retrofit at least 2,000 MW less: Georgia, Illinois, Iowa, North and South Carolina, Missouri, Ohio, Tennessee, and West Virginia. The increased use of low-sulfur coal would require additional capital expenditures of $0.6 billion (1980 dollars) to modify boilers or electrostatic precipitators, while the total expenditures for retrofits would be approximately $1.2 billion less.

Regional coal production would also shift as electric utilities use less bituminous medium-sulfur coal and more bituminous and subbituminous low-sulfur coal. Coal production from the Northern Great Plains would increase in 1995 by another 21 million tons, while production from Northern, Central, and Southern Appalachia would decrease by 21 million tons.

This comparison indicates that the economic choice on how to satisfy the required SO_2 reduction will be very sensitive to the cost of FGD systems. A 20-percent increase in the estimated capital cost of FGD results in less than half the projected amount of capacity being retrofit. Other factors beyond economics will also influence the compliance strategy of electric utilities. Few existing units today have retrofit with FGD systems because of the difficulty of adding such large structures into existing facilities and the reduced reliability of plants that have been modified. Hence, if FGD retrofits cost more than the $160/KW assumed in this study, or if non-economic factors dissuade utilities from using scrubbers, the capital costs of meeting S.3041 will be less, and the coal market shifts will be greater than projected in this report.

Financial Impacts of the Proposed Amendments

Significant financial costs are associated with the implementation of the proposed amendments. These include expenditures to retrofit existing units with FGD systems; modifications to boilers or electrostatic precipitators to burn low-sulfur or subbituminous coal; increased fuel expenditures by shifting to higher-priced coal; and the associated increase in operation and maintenance costs for units that retrofit with FGD equipment. Assuming that financial capital is available, these costs would be reflected in higher prices for electric power. Accordingly, the major financial impacts of the proposed legislation stem from the requirement to finance facilities that pollute less, and from the impact of these facilities on the average prices for electric power. These impacts are analyzed in this section.

Two broad assumptions are used to facilitate the analysis that follows. First, physical modifications to the existing plant and equipment are projected to occur mainly between 1990 and 1995 in order to meet the 1995 legislative requirement. Second, the amount of capacity modified each year is assumed to be evenly divided over time to ensure the least possible disruption to system reliability. The operational impact of these assumptions was then translated into financial outlays. These are classified into two distinct categories: non-recurring and recurring. The former includes capital expenditures necessary to modify or to install additions to existing plant and equipment; the latter takes into account expenditure increases resulting from modifications/additions and from such fuel/plant mix changes as become necessary to comply with the proposed legislation. These data were introduced into the National Utility Financial Statement model (NUFS). The model was then executed and the results were compared for the scenarios with and without the legislation.

Certain broad observations on the current health of the electric utility industry are in order before the results available from the NUFS simulation can be meaningfully interpreted and analyzed. As is well known, the electric utility industry continues to be the most capital-intensive sector in the domestic economy. This sector had few or no problems in raising the large amounts of capital that it needed through the 1960's. However, the overall environment in which the industry operated during the 1970's differed significantly from the relatively stable and favorable conditions that prevailed earlier. Substantial increases in the costs for fuel, labor, construction, operations and maintenance, and in interest charges combined to increase the cost of electric power generation. Lagging disposition of rate-adjustment requests in an environment of declining demand (resulting from the dual impact of the recession and the initiation of conservation in response to increases in the real price of electricity) created an unprecedented profit squeeze on the overall financial operations of many utilities. Utility stock prices declined and many were sold at or far below book values. Returns on equity dropped to their lowest levels since the 1960's. Those most seriously affected omitted dividends; others experienced serious difficulties in raising capital in the domestic financial markets. Partly as a result of this development, and partly as a result of reduced demand projections, significant new plant construction activity was either cancelled or postponed.[5]

This near-crisis situation no longer prevails. In fact, the industry has been recovering in the 1980's, even though the national economy has been in a recession. Industry analysts contend that the significant growth in industry earnings and its associated impact on the electric utilities' financial health result from regulators' efforts to strengthen industry financial position through favorable rate decisions. In addition, other factors contributing to this development include: the moderation of fuel price increases, realization of the beneficial impacts of recent changes in tax laws, modifications in the accounting procedures, and a lower-than-projected increase in peak load demand.[6]

Requirements for new financing necessary to support new plant and equipment for generation, and related transmission and distribution facilities, are estimated to be $374.5 billion (in 1980 dollars) in the case without S.3041. These requirements cover a 13-year period, 1983 to 1995, and include all of the electric utility industry, i.e., privately owned, municipal, State and power district systems, and cooperatives.[7] In addition, these estimates take into account the implementation of all existing pollution abatement legislation.

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[5] For a detailed discussion dealing with the financial vicissitudes of the electric utility industry, refer to Energy Information Administration, Office of Energy Industry Analysis, The Feasibility of Financing Domestic Energy Development During 1978-84, DOE/EIA-0184/2 (Washington, D.C., 1979), pp. 46-74. Also, Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Impacts of Financial Constraints on the Electric Utility Industry, DOE/EIA-0311 (Washington, D.C., 1982).

[6] These comments do not apply entirely to the quality of industry's earnings. For a fuller discussion of this subject, refer to Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Statistics of the Privately-Owned Electric Utilities in the United States 1981 (Washington, D.C., June 1983), and Appendix C.

Electric utilities in the 31 States specified by the proposed amendments account for nearly $273.5 billion (in 1980 dollars) of the total projected outlays in the base case without S.3041. Subsequent simulations focus on this geographic area and compare the case with implementation of the proposed amendments with the case without them. Four other sensitivity cases developed adopt the same methodology under varying demand and transportation cost assumptions. In each case, differences in cumulative capital costs (or requirements for financial capital) are computed and are shown in a format that breaks down the total expenditure requirements into appropriate segments. Average electricity prices in each case are also obtained from the NUFS simulation results. As indicated earlier, these results are obtained for all cases, with or without the implementation of the proposed amendments.

As shown in Table 6, the estimated incremental requirements of capital necessary to support the implementation of the proposed amendments under the various cases for 1995 range from a low of $7.2 billion (in 1980 dollars) in the low demand case to a high of $17.8 billion (in 1980 dollars) in the high demand case. These amounts represent the difference in cumulative capital expenditures with and without the proposed amendments for each case listed in Table 6.

These increments, however, do not include an allowance for funds during construction, that is, the cost of financing the construction work. The impact of this exclusion is not likely to be significant since retrofitting a unit with an FGD system is assumed to occur in 2 years and modifying a boiler or electrostatic precipitator is presumed to be completed in 1 year. Included in these estimates are, however, expenditures beyond FGD equipment and plant modifications to burn low-sulfur coal. These are the costs of additional new transmission lines and increased amounts of new capacity built by 1995 to reduce emissions through the retirement of older units. As a result, the cumulative expenditures projected in this report are higher than those reported in earlier studies.[8]

Expenditure data, as shown in Table 6, can be further disaggregated. In the base case, 8 of the 31 States affected by the legislation would each have an increase of more than $300 million in cumulative capital expenditures by 1995. These 8 States--Ohio, Georgia, Indiana, Michigan, Illinois, Missouri, Wisconsin, and Iowa--account for more than 70 percent of the increased expenditures.

In comparison with total industry outlays for the same period, these incremental capital or investment expenditures ranging from $7.2 billion to $17.8 billion by 1995 (both in 1980 dollars) translate into increases of 4.4 to 9.6 percent for the scenarios analyzed. For some individual utilities, however, the capital expenditures required to comply with S.3041 may represent a much higher percentage of their total outlays. Table 7 gives detailed results for a few key States.

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[7] Electrical World estimates these requirements to be $497.34 billion in 1982 dollars or about $426.71 billion in 1980 dollars. Differences between the two estimates are primarily attributable to timing and cost differences of capacity to be installed and exclusion of expenditures for new transmission and distribution systems. See Electrical World, Vol. 196, No. 6 (September 1982), pp. 83-86.

[8] Committee on Environment and Public Works, U.S. Senate, Clean Air Act Amendments of 1982, 97th Congress, Report No. 97-666 (Washington, D.C., November 1982).

Table 6. Cumulative Capital Expenditures Projected With S.3041 minus Those Projected Without S.3041 for the Base and Sensitivity Assumptions, in 31 States, 1983-1995[a]
(Billions of 1980 dollars)

Option	Base	Transportation Cost[b]		Electricity Demand	
		5%	9%	Low	High
FGD	2.8	4.5	6.0	1.6	5.5
Boiler Modification	2.1	1.7	1.5	1.4	1.9
Other[c]	3.7	3.9	3.6	4.2	10.4
Total	8.6	10.1	11.1	7.2	17.8

[a] This table contains the differences in the projected values for each case with S.3041 minus those projected without S.3041 in order to isolate the impacts of the proposed legislation.

[b] Compounded annually.

[c] Includes additional new transmission lines and new capacity.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Utility Financial Statement Model (NUFS), 1983.

The feasibility of financing incremental expenditures as presented in Table 6 will be governed by the overall state of the economy, the associated demand for electric power, and the cumulative needs for requirement for investment capital from external sources, i.e., the domestic capital markets.

These funds will normally be derived from two principal sources: internal sources, such as retained earnings, depreciation accruals, and deferred taxes; and external sources, such as the issuance of stocks and sale of bonds. Different costs and risks are associated with each source of financing. Reinvesting internally generated funds is usually assumed to be risk-free. The cost of these funds is the foregone interest that could be earned by investing the funds elsewhere at the going rate of interest in the market. Bond and/or equity financing costs are more than the imputed cost of internally generated funds. The true cost of borrowing includes the market rate of interest plus a risk premium associated with the firm's debt-servicing capability. When this composite cost rises above a critical point, equity financing is indicated. However, as the firm offers more stock, its price invariably declines and yields rise. Thus, the marginal cost of raising funds externally is invariably higher than that of raising them internally. External borrowing is undertaken to bridge the residual gap in total capital requirements only after internally generated funds have been exhausted.

Historically, the privately owned electric utilities have always relied heavily on external financing to meet their overall capital requirements, due to significant variations in the contribution of funds from internal sources. For example, in the

Table 7. SO_2 Emissions and Expenditures Projected With S.3041 Minus Those Projected Without S.3041 for the Base Assumption in Ten Key States[a]

State	Reduction in Projected SO_2 Emissions, 1995 (Thousand Tons)	Increase in Cumulative Capital Expenditures, 1983-1995 (Million 1980 Dollars)	Increase in Cumulative Capital Expenditures, 1991-1995 (Percent)	Increase in Annual Operating Expenses, 1995 (Million 1980 Dollars)	Increase in Average Price of Electricity, 1995 (1980 Mills per kWh)[b]
Ohio	1,358	1,037	10.9	168	2.5
Missouri	1,008	367	8.0	162	3.3
Indiana	1,001	577	5.7	176	2.0
Pennsylvania	738	185	1.2	87	1.2
Illinois	693	774	5.1	180	1.6
Wisconsin	526	364	25.5	160	3.8
Kentucky	510	137	2.0	54	0.2
W. Virginia	475	140	18.4	72	-1.5[c]
Tennessee	439	259	1.1	152	3.3
Michigan	250	398	5.0	-1[d]	0.6

[a] This table contains the differences in the projected values for the base case with S.3041 minus those projected without S.3041 in order to isolate the impacts of the proposed legislation.

[b] The 1982 average retail electricity price for privately owned utilities was 52.8 mills per kilowatthour in 1980 dollars.

[c] The decline in the average price of electricity is due to increased revenues from power transfers.

[d] The operating expenses are less because the expenditures on coal decline more than the increase in operating and maintenance costs due to more retrofits.

Sources: Energy Information Administration, National Coal Model (NCM), 1983; and National Utility Financial Statement Model (NUFS), 1983.

late 1950's and the early 1960's, nearly 60 percent of the total capital requirements were supplied by internally generated funds. In the subsequent decade, the increased tempo of construction activity and rising construction costs increased the need for external capital requirements to more than 70 percent, with less than 30 percent emanating from internal sources. Short-run technical rigidities associated with increasing the share of funds from internal sources, however, imply that the contribution of these funds has failed to increase significantly during the the late 1970's.[9]

Notwithstanding the improvements in the financial health of the privately owned utilities in 1981 and 1982, obvious constraints preclude a significant increase in the contribution of these funds during the 1980's.[10] Accordingly, the industry will continue to rely heavily on externally supplied capital from domestic capital markets to support new construction activities. Other things being equal, and assuming the allowed rate of return to be a policy variable, the degree of dependence on capital markets will vary directly as a function of the rate of inflation and its impact on interest rates during the period from 1983 to 1995. For the base case scenario, projections indicate that external financing requirements will continue to increase from their present levels during the 1980's.

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[9] For the 6-year period from 1975 to 1980, the average contribution of funds from internally generated sources works out to about 38.6 percent. Accordingly, the balance, i.e., 61.4 percent of the total construction funds, was acquired from external sources.

Capital expenditures associated with the proposed legislation are projected to occur predominantly during the 5-year period from 1991 to 1995. The ability to raise these funds by sale of tax-exempt bonds with the support of local and State authorities reduces their nominal cost significantly. The net nominal cost is further reduced by including interest payable as an expense to determine income before taxes. Finally, the construction leadtimes necessary to complete retrofits or modifications are such that all incurred expenditures will be incorporated in the rate base in less than 2 years in the majority of cases.

Impact on Electricity Prices

The average real price of electricity in the affected 31 States is projected to increase by 2.7 mills per kWh in 1980 dollars, or about 5.2 percent in 1995 in the base case with the implementation of the proposed amendments relative to the base case without the amendments. This increase is caused by two differing but interacting factors. First, increased capital outlays necessary to modify existing plants or to add new capacity to compensate for derating are included in the rate base. Second, operating and maintenance expenses of the modified plants go up. In addition, there are the usual incremental operations and maintenance expenses on new capacity installed. For 1995, details relative to the increase in operating and maintenance expenditures are shown in Table 8. These increments are reflected in the average real price of electricity.

The maximum impact on average real prices of electricity in 1995 is occasioned by changes in the demand for electricity. In the case of high demand, the 1995 prices (with the proposed amendments) are projected to increase by 3.7 mills per kWh. In fact, the reported price impact in this case contains a downward bias because the price-quantity relationship cannot be included within the NUFS model. In contrast, the transportation cost cases (5 percent and 9 percent) with the proposed amendment yield prices in 1995 that are projected to be 3.0 mills per kWh more than in the transportation cases without the proposed amendment.

The projected rate increases include only the impact of SO_2 emissions reductions. As stated previously, this study projects higher capital expenditures because more capacity is projected to retrofit with FGD equipment, and costs to modify boilers or precipitators to burn low-sulfur coal are also included. Regional variations in these prices will depend on the amount of retrofitting or modification necessary to comply with the proposed amendments.

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[10] Some improvement will no doubt be perceptible in the level of accruals from internally generated funds as more expensive newer plants are included in the rate base. However, its impact on the relative share may not be significant.

Table 5. Increases in Operating and Maintenance and Fuel Expenses Projected With S.3041 Minus Those Projected Without S.3041 for the Base and Sensitivity Assumptions in 31 States, 1995[a]
(Billions of 1980 Dollars)

		Transportation Cost[b]		Electricity Demand	
Components	Base	5%	9%	Low	High
O & M	0.3	0.5	0.7	0.4	0.4
Fuel	2.3	3.6	3.9	0.3	6.3
Coal	2.0	2.8	1.4	1.9	3.4
Total[c]	2.6	4.1	4.6	0.6	6.7

[a] This table contains the differences in the projected values for each case with S.3041 minus those projected without S.3041 in order to isolate the impacts of the proposed legislation.

[b] Compounded annually.

[c] Includes operating and maintenance and fuel costs only. Coal cost are included in the fuel costs.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM) 1983.

5. IMPACT OF PROPOSED AMENDMENTS ON THE COAL INDUSTRY

Introduction

In the late 1970's, coal use in the United States began to increase significantly. This trend of increasing coal consumption is expected to continue. The Demonstrated Reserve Base (DRB) of coal in the United States is immense in relation to current and projected production rates. The recoverable portion of the DRB is estimated to be at least 236 billion short tons.[1] The coal reserves are distributed over large areas of the United States (see Figure 6). Most of the bituminous coal reserves are located east of the Mississippi River, predominantly in Illinois, Pennsylvania, West Virginia, and Kentucky. The western bituminous coal reserves are located largely in Utah and Colorado. All of the subbituminous coal reserves are located in western States, largely in Montana and Wyoming. Lignite reserves are located chiefly in the western States, including Montana, Texas, North Dakota, and Louisiana. Since Louisiana lignite reserves are not represented in the model, consumption and production quantities for lignite are understated in this analysis.

One of the characteristics of the quality of coal is its Btu content. Bituminous coal contains 20 or more million Btu (MMBtu) per ton; subbituminous coal contains between 15 and 19.99 MMBtu per ton; lignite contains less than 15 MMBtu per ton. Another factor to be considered in coal quality is its classification by sulfur content. Low-sulfur coal (less than 1.2 pounds of sulfur dioxide per MMBtu) is generally cleaner to burn. West Virginia, Montana, and Wyoming have the largest reserves of low-sulfur coal in the contiguous United States (see Table 9).

This chapter of the report will focus on two issues. The first addresses the impact on coal production of the implementation of Senate bill S.3041. The second addresses how regional coal production patterns will change, assuming S.3041 is implemented, if transportation rates are higher than those assumed in the base case, or if demand for electricity is higher or lower than assumed in the base case. For this analysis, electricity demand is fixed and not price-sensitive. Electric utility demand for coal depends on the assumed level of demand for electricity, the amount of existing and new coal-fired capacity in each region, and the least-cost means of satisfying demand for electricity. However, demand for coal by other sectors is fixed for all scenarios.

As a result of the projected increase in coal demand through 1995 without S.3041, production of bituminous coal and lignite is projected to increase from 824 million tons in 1980 to 1.3 billion tons in 1995 (see Table 10). The share of total coal production from the East is projected to decrease from 70 percent in 1980 to 63 percent in 1995. This decrease, which started in the early 1970's, is a result of the more rapid growth in demand for coal in the West, and the availability of inexpensive western low-sulfur, low-Btu coal for eastern as well as western markets.

The projected changes in coal production among the cases reflect the market response to changes in delivered coal prices, expressed in dollars per million Btu. The primary response to S.3041 is a redistribution of the type of coal demanded, particularly by sulfur content.

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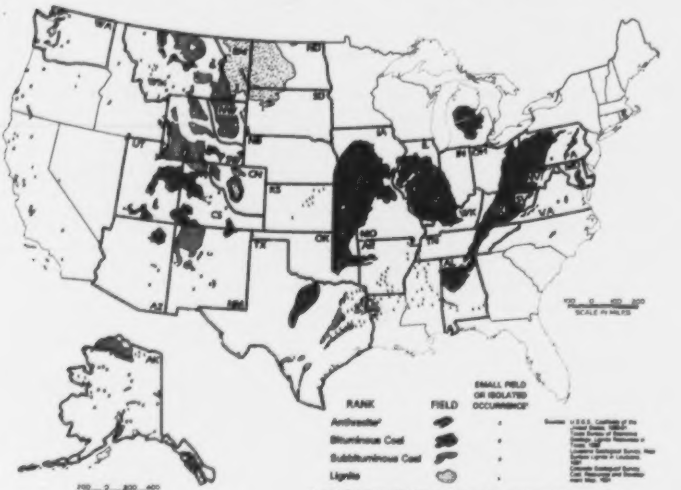
[1] Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Demonstrated Reserve Base of Coal in the United States on January 1, 1980, DOE/EIA 0280(80) (Washington, D.C., 1982).

Figure 6. Coal-Bearing Areas of the United States


WA
MT
ND
SD
WY
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UT
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KS
IA
IL
IN
OH
PA
WV
VA
MO
OK
AR
TN
AL
TX
NM
AZ
AK
SCALE IN MILES
SCALE OF ALASKA ONE HALF THAT OF CONTIGUOUS UNITED STATES
RANK
FIELD
SMALL FIELD OR ISOLATED OCCURRENCE1
Anthracite2
Bituminous Coal
Subbituminous Coal
Lignite

1 Symbolic representation; these small areas or data points cannot be shown to scale.
2 Principal anthracite deposits are in Pennsylvania. Small deposits occur in Alaska, Arkansas, Colorado, Massachusetts-Rhode Island, New Mexico, Utah, Virginia, Washington, and West Virginia.

Supply Region Definitions

Northern Appalachia
  Pennsylvania (PA)
  Ohio (OH)
  Maryland (MD)
  West Virginia, north (NV) a/
Central Appalachia
  West Virginia, south (SV)
  Virginia (VA)
  Kentucky, east (EK)
  Tennessee (TN)
Southern Appalachia
  Alabama (AL)
Midwest
  Illinois (IL)
  Indiana (IN)
  Kentucky, west (WK)
Central West
  Iowa (IA)
  Missouri (MO)
  Kansas (KS)
  Arkansas (AR)
  Oklahoma (OK)
Gulf
  Texas (TX)
Eastern Northern Great Plains
  North Dakota (ND)
  South Dakota (SD)
  Montana, east (EM) b/
Western Northern Great Plains
  Montana, west (WM)
  Wyoming, northeast (NW) c/
  Wyoming, southwest (SW)
  Colorado, north (CN)
Rockies
  Colorado, south (CS)
  Utah (UT)
Southwest
  Arizona (AZ)
  New Mexico (NM)
Northwest
  Washington (WA)
Alaska
  Alaska (AK)

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a/ Includes all of Nicholas County.
b/ Includes the following counties: Carter, Daniels, Fallon, McCone, Prarie, Richland, Roosevelt, Sheridan, Valley and Wibaux.
c/ Includes all of Campbell County.
Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

Table 9. Demonstrated Reserve Base (DRB) of Low-Sulfur Coal for Selected States[a] as of January 1, 1980
(Million Short Tons)

State	Low-Sulfur DRB	Total DRB	Percentage of Low-Sulfur to DRB
Penn.	426	30,281	1
W. Va.	12,806	39,776	32
Va.	2,254	3,471	65
Kentucky	5,321	34,002	16
Wyoming	36,147	69,924	52
Colorado	8,864	17,281	51
Montana	118,315	120,428	98
Utah	3,193	6,478	49
N. Mexico	1,822	4,521	40

[a] States in the contiguous United States that have more than 2,000 million tons of coal, including low-sulfur coal, in the DRB.

Sources: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Documentation of the Reserve-Related Data Inputs to the Resource Allocation and Mine-Costing Model, DOE/NBB-0026 (Washington, D.C., September 1982); and Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Demonstrated Reserve Base of Coal in the United States on January 1, 1980, DOE/EIA-0280 (80) (Washington, D.C., May 1982).

Electric utilities are the largest consumers of coal in the United States, and are projected to account for 72 percent of the market in 1995. Any major shift in demand from this sector has a heavy impact on the coal industry. In the base case with S.3041, total U.S. coal production is 1.32 billion tons in 1995, a 2-percent increase over the base case without S.3041. This rise is due to the increased demand for low-sulfur, low-Btu coal from the West. In order to meet the same level of demand, more tonnage is required because of the lower Btu content of western coal. The mix in production between East and West also changes with the introduction of the new pollution abatement legislation because western coal generally has lower sulfur content. In the base case, eastern regions are projected to supply 63 percent of U.S. coal production. However, with the S.3041 provisions in place, the eastern share of total production is projected to decline to 60 percent.

Utilities are expected to meet emission standards in the base case with S.3041 by burning more low-sulfur coal than in the base case without S.3041, because that is the most cost-effective option. By 1995, in the base case with S.3041, the price of coal delivered to the electric utilities is projected to increase $1.34 per ton (1980 dollars), nationally, over the base case without S.3041. This increase in price is due to the shift in demand to higher-cost low-sulfur coal from Central Appalachia and to more distant low-sulfur western coal. However, if transportation costs are higher, or if electricity demand is lower or higher than assumed in the base case, a different mix of options is expected to be selected by utilities to meet the proposed emission standards.

Table 10. U.S. Bituminous Coal and Lignite Production, 1980 and 1995
(Million Short Tons)

Region[a]	History 1980	Base Case w/o S.3041 1995	Base Case w/ S.3041 1995
Northern Appalachia	178	242	203
Central Appalachia	234	346	439
Southern Appalachia	26	34	31
Midwest	134	198	111
East[b]	573	820	784
Central West	13	37	23
Gulf	29	101	102
E. Northern Great Plains	17	40	36
W. Northern Great Plains	125	177	247
Rockies	31	54	57
Southwest	29	59	61
Northwest	6	7	6
West[c]	251	476	532
Total United States	824	1296	1316

[a] See Figure 6 for definition of regions.

[b] States east of the Mississippi River.

[c] States west of the Mississippi River.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Weekly Coal Production, DOE/EIA-0218 (81/42) (Washington, D.C., October 23, 1981).

Impact On Coal Supply Under The Base Cases

In the base case with S.3041, electric utilities in the 31 States shift their demand in 1995 from medium- and high-sulfur coal toward low-sulfur coal. Low-sulfur coal consumption by these utilities is projected to increase 246 million tons (147 percent) above the base case without S.3041, and medium- and high-sulfur coal consumption are projected to decrease by 104 million tons (32 percent) and 121 million tons (72 percent), respectively, in the base case with S.3041.

Since the electric utilities in the 31 States are projected to consume 70 percent of all coal consumed by utilities in 1995, such a shift in coal demand causes regional shifts in coal supply. The shifts in the base case with S.3041 are most notable in the predominantly medium- and high-sulfur coal producing regions of Northern Appalachia, the Midwest, and Central West, where coal production is expected to decrease significantly from the base case without S.3041; and in the predominantly low-sulfur coal producing regions of Central Appalachia and the Western Northern Great Plains, where production is expected to increase.

In the Pennsylvania and Ohio portions of northern Appalachia, coal production is projected to decrease in 1995 by 20 million tons and 16 million tons, respectively, as the demand for high-sulfur coal decreases with implementation of the proposed legislation. In the Midwest, coal production in Illinois and Indiana is projected to decline by 37 million tons and 14 million tons, respectively. Central Appalachia, with its low-sulfur coal reserves, is projected to increase production by 93 million tons.

Coal production in the Western Northern Great Plains is projected to increase significantly due to the vast resources of low-sulfur subbituminous coal. The major beneficiary of this increase is Wyoming, where coal production is projected to increase by 62 million tons. Other western States that have large reserves of low-sulfur coal, i.e., Colorado, New Mexico, and Utah, either have higher mining costs than Wyoming or lack the transportation infrastructure to develop their resources for shipment to the 31 States.

Since approximately 25,000 megawatts of capacity in Pennsylvania and Ohio are classified as mine-mouth capacity (i.e., plants sited near their coal supplies), it is unlikely that all of these plants would switch to lower-sulfur coal. Instead, it is probable that the plants supplied by captive mines (about 10,000 MW) would continue to burn medium- or high-sulfur coal, as projected by this analysis. If the remaining mine-mouth capacity cannot switch to low-sulfur coal as projected here, then the decrease in coal production in these two States may be overstated.

Comparison of Cases With S.3041

If the requirements imposed by S.3041 are in place in 1995, the uncertainty of future transportation rates (further increases beyond those initiated by the Staggers Rail Act of 1980), and the uncertainty in the growth of electricity demand make it necessary to examine the sensitivities about the base case with S.3041. For this analysis, two transportation cases were considered. The cases reflect transportation rates that would increase in real terms by 5 percent and 9 percent per year, compounded annually, over the base case. The uncertainty in electricity demand is represented in sensitivity cases by low electricity demand (1 percent per year, compounded annually, less than in the base case) and high electricity demand (1 percent per year, compounded annually, greater than in the base case). Tables in this chapter do not show differences, as in other chapters, but show levels associated with scenarios that include the legislation.

Utilities are expected to respond to increased transportation rates in 1995 by retrofitting more capacity with FGD equipment than in the base case with S.3041. In the 5-percent transportation case, an additional 13 gigawatts of capacity is projected to be retrofit, and in the 9-percent case, an additional 21 gigawatts is projected to be retrofit. This response results in a projected switch in demand from low-sulfur coal to medium- and high-sulfur coals in both cases (see Table 11). This switch by utilities causes a shift in the type of coal produced (see Table 12). Utilities near high-sulfur coal producing regions find that the increased cost of obtaining low-sulfur coal from greater distances is sufficient to warrant installation of FGD equipment, to permit the use of nearby high-sulfur coal.

Table 11. Coal Types Consumed by Utilities in the 31 States, With S.3041, 1995 (Million Short Tons)

Rank/ Sulfur Content	Base Case	With S.3041			
		Transportation Cost[a]		Electricity Demand	
		5%	9%	Low	High
Bituminous					
Low-Sulfur	272	259	237	203	306
Medium-Sulfur	186	216	237	190	182
High-Sulfur	47	65	100	50	35
Total	505	540	574	443	523
Subbituminous					
Low-Sulfur	134	85	44	124	158
Medium-Sulfur	18	18	8	17	21
High-Sulfur	0	([b])	([b])	0	0
Total	152	103	52	141	178
Lignite[c]					
Low-Sulfur	2	2	2	0	0
Medium-Sulfur	13	17	6	12	10
High-Sulfur	0	0	0	0	0
Total	15	19	8	12	10
Total					
Low-Sulfur	407	346	284	327	464
Medium-Sulfur	217	251	250	219	213
High-Sulfur	47	65	100	50	35
Grand Total	672	662	634	596	712

[a] Compounded annually.

[b] Less than 0.5.

[c] Lignite consumption is understated because Louisiana lignite reserves are not represented in the model.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

Table 12. U.S. Bituminous Coal and Lignite Production by Coal Type--Base Case and Sensitivity Cases, With S.3041, 1995 (Million Short Tons)

Rank/ Sulfur Content	Base Case	With S.3041 Transportation Cost[a] 5%	 9%	 Electricity Demand Low	 High
East[b]					
Bituminous					
Low-Sulfur	273	276	260	246	278
Medium-Sulfur	375	397	400	347	374
High-Sulfur	136	151	178	137	129
Total	784	824	839	730	781
Total East	784	824	839	730	781
West[c]					
Bituminous					
Low-Sulfur	98	103	116	82	123
Medium-Sulfur	12	11	25	9	15
High-Sulfur	14	22	32	15	16
Total	125	136	172	106	155
Subbituminous					
Low-Sulfur	189	134	85	178	220
Medium-Sulfur	80	66	43	80	88
Total	269	199	128	258	308
Lignite[d]					
Low-Sulfur	3	3	4	1	1
Medium-Sulfur	129	132	122	125	126
High-Sulfur	6	7	7	6	6
Total	139	142	132	133	133
Total West	532	477	433	496	596
Total United States					
Low-Sulfur	563	515	465	507	623
Medium-Sulfur	597	606	590	561	603
High-Sulfur	157	180	217	159	151
Grand Total	1,316	1,301	1,271	1,226	1,377

[a] Compounded annually.

[b] States east of the Mississippi.

[c] States west of the Mississippi.

[d] Lignite production is understated because Louisiana lignite reserves are not represented in the model.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

In the case of high transportation costs, coal production in Central Appalachia and the Western Northern Great Plains regions is projected to be less since these two regions are the main supply regions for low-sulfur coal (see Table 13). Utilities are expected not to use low-sulfur coal and, instead, retrofit with FGD equipment because it is the least expensive method to meet the standards. Since most of the low-sulfur coal is from the West and has lower Btu content, the cost per Btu of shipping the coal more than outweighs the additional capital and operating expense of using FGD equipment to achieve compliance.

The national average price of coal delivered to utilities in 1995 is projected to increase over the base case with S.3041 by $9.05 per ton (1980 dollars) in the 5-percent transportation case, and by $18.28 per ton (1980 dollars) in the 9-percent transportation case (see Table 14).

In the low electricity demand case, utilities retire fewer old plants that were burning high-sulfur coal and do less switching to low-sulfur bituminous coal than in the base case. The reason is that there are fewer emissions to be offset due to the lower electricity demand. Therefore, based on utilities' decisions in the low electricity demand case, the medium- and high-sulfur coal demand increases over that of the base case with S.3041. In response to this shift in demand, Midwest coal production increases slightly over that in the base case with S.3041. The national average price of coal delivered to utilities in 1995 is projected to be $35.65 (1980 dollars) per ton in this case compared with $36.51 per ton (1980 dollars) in the S.3041 base case.

Utilities faced with higher electricity demand are expected to retrofit more plants with FGD equipment than in the base case, because there is a higher level of emissions to be offset due to more intensive use. Some existing plants that could burn medium- and high-sulfur coal without retrofitting, in the base case with S.3041, would either have to retrofit to use those coals or would use low-sulfur coal. The utilities are expected to burn more low-sulfur coal and less medium- and high-sulfur coal in this case. The increase in demand for low-sulfur coals is seen in the significant increase in production in the Western Northern Great Plains and the Rockies. The national average delivered coal price to utilities in this case is projected to be $38.35 per ton (1980 dollars) compared to $36.51 per ton (1980 dollars) in the S.3041 base case.

Other Impacts of Proposed Amendments on Coal

The projected shifts in coal supply that occur in the base case with S.3041, and in the sensitivity cases, would likely cause a redistribution of employment in the coal mining industry. Since coal production grows or remains the same during 1980 to 1995 in all regions but the Midwest, coal mine employment in that region would decline; however, opportunities would be available in other regions. In examining the sensitivity cases, only one other region, namely the Western Northern Great Plains in the 9-percent transportation case, is expected to decrease coal production below the 1980 levels, which could cause a shift in coal mine employment opportunities. As with employment, State revenues from coal severance taxes will be redistributed in the same areas.

The projected increase by 56 million tons in western coal production in 1995, in the base case with S.3041, could place new burdens on the present capacity of the U.S. transportation system. However, because of the long leadtimes required to construct

Table 13. U.S. Bituminous Coal and Lignite Production--Base Case and Sensitivity Cases, With S.3041, 1995 (Million Short Tons)

		With S.3041			
		Transportation Cost[a]		Electricity Demand	
Region[b]	Base Case	5%	9%	Low	High
Northern Appalachia	203	207	211	200	199
Central Appalachia	439	430	401	386	444
Southern Appalachia	31	41	47	31	30
Midwest	111	146	179	113	108
Central West	23	30	53	21	25
Gulf	102	102	103	102	102
E. Northern Great Plains	36	40	29	31	31
W. Northern Great Plains	247	180	119	232	288
Rockies	57	53	52	50	83
Southwest	61	60	63	55	58
Northwest	6	12	14	6	9
Total	1,316	1,301	1,271	1,226	1,377

[a] Compounded annually.

[b] See Figure 6 for definition of regions.

Note: Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

Table 14. National Average Coal Prices Delivered to Utilities, With S.3041, 1995 (1980 Dollars per Short Ton)

		With S.3041			
		Transportation Cost[a]		Electricity Demand	
	Base Case	5%	9%	Low	High
National Average	36.51	45.56	54.79	35.65	38.35

[a] Compounded annually.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, National Coal Model (NCM), 1983.

electric power facilities and to open western coal mines, the projections assume that the required transportation facilities can be planned, constructed, and made available when required. Uncertainty exists primarily because it is difficult to plan for expansions, due to fluctuations in the coal market. Moreover, capital costs associated with upgrading transportation facilities are considerable. Coal slurry pipelines could play a large role in transporting western coal. Potentially, they can transport large volumes of coal economically and efficiently over long distances. However, they have long leadtimes for construction and assembling rights-of-way and water rights. With the leadtime available under S.3041, the transportation system should be available to handle the increased amount of coal projected to be supplied from the West.

6. POTENTIAL BENEFITS OF REDUCING SULFUR DIOXIDE EMISSIONS

As noted in Chapter 4, the projected capital expenditure required to reduce utility sulfur dioxide (SO_2) emissions by 8 million tons as proposed by the Clean Air Act Amendments of 1982 is $8.6 billion. Neither the specific benefits to be obtained from that reduction nor their value is known. Nevertheless, this chapter identifies from available literature the general categories of potential benefits that may result from major cutbacks in SO_2 emissions. The chapter reviews the difficulties described in the literature associated with estimating such benefits and presents possible dollar ranges of those benefits. This information is drawn solely from the literature and does not represent judgments by EIA as to the benefits of reducing SO_2 emissions.

The potential benefits of reducing SO_2 emissions are improvements in air quality and the damages avoided as a result of the reductions in acid deposition. These benefits include: (1) avoiding the additional damages that may result from any increases in emissions, (2) avoiding any continuation of damages that may result from current emissions, and (3) any positive recovery of the environment over and above avoided damages. Emission control technologies may in time provide positive economic by-products, such as gypsum, but currently their anticipated contribution is negligible.

Potential benefits accrued by avoiding damages are classified in the literature among four separate groups: water and wildlife, forestry and agriculture, man-made products, and human health.

Water and Wildlife

Losses of fish in New York's Adirondack mountains and other Northeastern areas comprise the most publicized and least controvertible damage attributed to acid deposition. More than 180 Adirondack lakes have lost fish populations.[1] Increasing evidence indicates that damages also occur to lifeforms lower in the food chain, and to the fish and mammals dependent on them. In the view of some, these damages, if left unchecked over long periods of time, could eventually lead to irreversible serious environmental effects. These effects have been characterized in the literature as a possible environmental crisis or disaster.[2]

Those who hypothesize that these damages are caused by acid deposition cite correlations of large measured increases in water acidity with drops in fish and other food chain populations. Others challenge the relevance of these measurements and observations, or emphasize that natural causes, such as runoff from naturally acidic soils, could be the cause of lake acidification.

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[1] G.E.Bangay and C. Riordan, eds, Work Group I, "United States-Canada Memorandum of Intent on Transboundary Air Pollution," Final Report (1983), p. 3-127.

[2] National Academy of Sciences, Committee on the Atmosphere and Biosphere, Atmosphere-Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion, National Academy Press (Washington, D.C., 1981), pp. 2-3; and Electric Power Research Institute, "Acid Deposition: Decision Framework, Volume 1: Description of Conceptual Framework and Decision Tree Models," Final Report, EPRI RP 2156-1 (Palo Alto, California, August 1982), p. 20.

Forestry and Agriculture

Increasingly, proponents of SO_2 control are attributing forest damages to acid deposition. Declines of spruce, fir, beech, pine, and maple trees in the New York Adirondacks, Vermont Green Mountains, and other Northeastern areas have been ascribed to acid rain.[3] Experimental evidence suggests that acid deposition leaches plant nutrients, raises soil acidity, and inhibits decomposition, and that deposition damages leaf surfaces.[4] However, neither forest nor agricultural damages are proven to have been caused by acid deposition. Occasionally, positive effects of acids have been noted among research results, such as increases in soybean yields.[5] Damage has not been observed in field crops, and possible soil damage could be offset by marginal increases in field liming. Acid rain has been called merely "a viable hypothesis" in the decline of forests.[6]

Man-made Products

Perceived damages to man-made structures include deterioration of water systems and appliances, decay of buildings, textile rot, destruction of artworks and damage to historic structures. Acid deposition is believed by some to accelerate corrosion, discoloration, and embrittlement of materials. Acid deposition is also believed to bleach and crystallize paints and cause wood, paper, leather, and textiles to deteriorate, fade, and discolor.[7]

Evidence of damages to man-made structures from acid rain is less accepted than claims of damages to water and wildlife, or to forestry and agriculture. Where damages to structures from acid deposition are conceded to exist, strong arguments also suggest that local sources of pollution are responsible, rather than deposition from distant sources.

Human Health

Human health damages are potentially the most important but at the same time the least convincingly demonstrated effects of acid deposition. A recent study by the Office of Technology Assessment attributes thousands of premature urban deaths and many more illnesses to respiration of sulfates and other suspended particles.[8] Nevertheless, evidence of health damages is both scant and controversial; opponents fault health effects arguments for attributing urban deaths to deposition from distant sources rather than to local pollutants, such as local industrial and automobile emissions; for citing sulfur as the cause, rather than as merely an index of pollutants; and for applying to the whole population effects that are applicable only to persons suffering from respiratory illnesses.

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[3] H.W. Vogelmann, "Catastrophe on Camels Hump," Natural History, Vol. 91, No. 11, (November 1982), p. 14.

[4] National Academy of Sciences, pp. 167-182.

[5] National Academy of Sciences, p. 167.

[6] U.S. Office of Technology Assessment, "The Regional Implications of Transported Air Pollutants: An Assessment of Acidic Deposition and Ozone," Interim Draft Report (1982), p. F-8.

[7] "Methods Development for Assessing Acid Deposition Control Benefits," Draft Report to the Environmental Protection Agency (no date) by Thomas D. Crocker, John T. Tschirhart, Richard M. Adams, and Bruce Forster, p. 48.

Estimating the Benefits of Reducing Sulfur Emissions

Significant scientific and economic difficulties prevent any accurate or widely accepted estimates of benefits from reducing SO_2 emissions. Fundamental information is lacking as to the quantity of damages; how changes in emissions are related to changes in acid deposition; how changes in acid deposition are related to changes in damages; and how both damages and benefits may be valued. Scientists do not know the degree to which reducing utilities' SO_2 emissions will reduce acid rain damages. If damages are not caused by the emissions or are irreversible, no benefits would be gained from the reduction. On the other hand, if damages caused by SO_2 emissions are reversible and more than proportional to emissions cutbacks, benefits from the cutbacks could be very large. Further, if continued emissions at current or increased levels are leading to irreversible and serious environmental effects as is sometimes contended, the benefits of the proposed cutbacks could be overwhelming.

Economists have great difficulty in assigning dollar values to the damages, even if the damages at various emissions levels are assumed to be known. Many damages hypothesized to be caused by acid rain are only barely perceived as having social or human importance. Society's ability to adapt to changes possibly required by acid rain damages is not known. In addition, there is great reluctance to set a price on reductions in human lifespan and health. Thus economists charged with pricing the benefits of reducing emissions do so under very arbitrary assumptions, with a high probability of significant error, and with an expectation of controversy. In fact, dollar estimates are generally avoided; no generally accepted estimates exist.

Available evidence on the dollar value of benefits that may be obtained from reducing emissions suggests three very broad ranges of benefits: (1) improvements of zero to $5 billion to U.S. water and wildlife, forestry and agriculture, and man-made products; (2) improvements from zero up to some billions of dollars in health improvements and avoided premature deaths in the United States; and (3) a zero-to-near-infinite benefit of avoiding the uncertain possibility of irreversible and serious environmental effects.[9]

If few or no benefits result from reducing emissions, the costs of those reductions may not be justified; on the other hand, should improved information corroborate irreversible and serious environmental damages, the benefits of reducing emissions may outweigh the expected costs. If health is affected, the total value of expected benefits becomes large. Society may elect to insure itself, whatever the uncertainties. Nevertheless, at this time only damages to lakes and fish are widely accepted as sufficiently demonstrated. Lake-liming is often cited as a direct and inexpensive response to such aquatic damages. Other damages and possible benefits are not currently proven, and involve various degrees of speculation. Overall, benefits from reductions in emissions may mitigate costs. For the time being, however, it is unclear whether the actual benefits resulting from reducing emissions will fall short of, equal, or exceed projected costs.

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[8] U.S. Office of Technology Assessment, pp. J-7,8.

[9] The discussion of economic difficulties and dollar ranges is derived from other summary works, particularly Crocker et al., "Methods Development for Assessing Acid Deposition Control Benefits," and Air and Water Pollution Control, A Benefit-Cost Assessment, by A. Myrick Freeman III (New York: John Wiley and Sons, 1982).

7. CONCLUSIONS

Findings of This Study

The changes proposed by the Clean Air Act Amendments of 1982 would result in a reduction of over 50 percent in the amount of SO_2 projected to be emitted by electric utilities in 1995. However, this represents only 20 percent of the natural and man-produced SO_2 and NO_x emitted in the 31 States in 1980. (See Appendix B.)

Major findings of this report assessing the impacts of the proposed legislation are summarized below:

- Switching to low-sulfur coal is projected to be the preferred choice of electric utilities to reduce SO_2 emissions. Capital expenditures are not required for 60 percent of the boilers that convert to low-sulfur coal. However, if the transportation rates for shipping coal increase substantially, utilities in the Midwest would likely continue using high-sulfur coal produced in their own or nearby States, and would retrofit more power plants with an FGD system.

- Cumulative capital expenditures in the 31 States affected by the proposed legislation are projected to increase by \$7.2 billion to \$17.8 billion, in 1980 dollars, for the range of scenarios considered. Most of this increase occurs from 1991 through 1995 and represents 4.4 to 9.6 percent of projected total capital expenditures by all utilities in the 31 States for that period.

- Average electricity prices are projected to increase by 0.9 to 3.7 mills per kilowatthour across the various scenarios in 1995, as utilities must recover higher capital expenditures, fuel expenditures, and operating and maintenance costs. The 1982 average retail electricity price for privately owned utilities was 52.8 mills per kilowatthour in 1980 dollars.

- The coal industry is likely to experience large shifts in the amount of coal produced in the different regions. In the Midwest, coal production is projected to drop below its 1980 level, and in Northern Appalachia and the Central West coal production is projected to grow at a slower rate than currently expected. Central Appalachia and the Western Northern Great Plains are projected to increase their production since the legislation benefits the producers of low-sulfur coal.

- Five States--Ohio, Missouri, Indiana, Pennsylvania, and Illinois--that account for 50 percent of the projected reduction in 1995 SO_2 emissions would have higher electric utility capital expenditures, higher electricity prices, and lower State coal production with this legislation. In the base case with the legislation minus the base case projected without it, the increases in capital expenditures for the five States range from \$185 million to \$1,037 million (in 1980 dollars). Electricity prices increase 1.2 to 3.3 mills per kilowatthour (in 1980 dollars) among the five States, and State coal production in 1995 would decline by 0.3 to 37 million tons.

Benefits from the proposed amendments include improvements in air quality. Additional environmental benefits may occur from improved water and wildlife, agriculture and forestry, greater longevity of man-made structures, and better human health. Because such benefits are as yet unproven, it cannot be determined if their value will be more than, less than, or equal to the total costs of reducing emissions.

Comparison with Other Studies

The following studies have also been produced analyzing Senate Bill S.3041 or S.768, a similar bill, introduced in the 98th Congress:

- ICF, Inc., Analysis of a Senate Emission Reduction Bill (S.3041), Report for the Environmental Protection Agency (EPA), February 1983.
- National Economic Research Associates, Inc. (NERA), A Report on the Results from the Edison Electric Institute Study of the Impacts of the Senate Committee on Environment and Public Works Bill on Acid Rain Legislation (S.768), Prepared for the Edison Electric Institute, June 20, 1983.
- Peabody Holding Company, Inc., Economic Impacts of Senate Environment and Public Works Committee Acid Rain Legislation 1983.

Comparisons of the results of this EIA study with other analyses are included here to highlight the differences and similarities in the findings. Since the other reports do not address the sensitivity of the projections to different assumptions about the rate of growth in electricity demand or changes in railroad rates for shipping coal, only the results for the EIA base case are included for comparison.

Each study reports projected cost and coal production impacts in different ways. For example, some studies project increases in the annualized costs of producing electricity and others project capital expenditures and revenue requirements. Also, the methods used to estimate these impacts vary from study to study. This section briefly discusses each methodology, the underlying assumptions, the actual published values and how those values are adjusted for comparison and explains the differences.

Methodology

The projections included in this report and in the EPA report prepared by ICF, Inc., use similar linear program models of coal production and electric utility dispatching. The projections are developed by minimizing the marginal cost of producing electricity in each region, given constraints on the amount of available capacity and the required reduction in SO_2 emissions. This approach assumes that the utilities in each region operate similarly to a centrally dispatched power pool, and that decisions on how to reduce SO_2 emissions are based on an economic choice.

In addition, financial impacts were projected for the EIA study with a financial accounting model called the National Utility Financial Statement Model. Income statements, balance sheets, and other financial factors are developed for each region, based on construction and dispatch decisions forecast by the linear programming model and on State Public Utility Commission rate-making practices.

The NERA report prepared for the Edison Electric Institute (EEI) is based on a survey of 24 utilities in the 31 States affected by the legislation. Most utilities in the survey compared the long-term cost effectiveness of retrofitting with FGD versus fuel switching for each plant. These companies would account for 44 percent of the 8-million-ton reduction in SO_2 emissions required by the legislation. The utilities provided estimates of how the reduction would be achieved and the costs of their compliance strategies.

The Peabody Holding Company report was developed with an accounting model that calculated the cost for each plant to reduce SO_2 emissions by the required amount. It was assumed that low-sulfur coal would be used whenever possible to satisfy an emission limit that was equal for all plants in a State. When low-sulfur coal could not meet this emission standard, it was assumed that the plant would retrofit with FGD equipment.

Underlying Assumptions

The underlying assumptions of the various studies of the impacts of S.3041 are shown in Table 15. The major differences in the underlying assumptions are discussed below.

All four studies in Table 15 are based on the State apportionment of the 8-million-ton annual reduction in SO_2 emissions specified in the legislation. The EIA study is based on intrastate trading of SO_2 reductions, with a small amount of interstate trading (up to 5 percent of each region's SO_2 emission limit). The EPA study prepared by ICF, Inc., has three methodologies: intrastate trading, interstate trading, and an emission limit of approximately 1.5 pounds of SO_2 per million Btu for each unit. For comparison purposes, the cost data from the intrastate methodology were used from the EPA study.

The EEI report is based on the assumption that each utility will meet a required reduction in emissions. The required State reduction was apportioned among sources within each State, based on 1980 emissions in excess of 1.5 pounds per million Btu. The Peabody Holding Company applied the State apportionment of the 8-million-ton reduction to individual power plants and assumed that each power plant in a State would satisfy the same emission standard.

The EIA and EPA studies have a phased implementation to reduce SO_2 emissions, while the EEI and Peabody Holding Company reports provide impacts for the first year the legislation is in effect, and EEI also gives 5-year levelized effects. Both the EPA and Peabody studies offset industrial SO_2 emission growth, and in addition the EPA report reduced industrial SO_2 emissions. The electricity demand growth in the EIA study varies by region, with a national increase of 2.9 percent annually from 1980 to 1995, compared with the EPA study figures of 1.5 percent from 1983 to 1985 and 2.7 percent from 1985 to 1995.

The FGD retrofit costs used in the studies vary considerably. In 1980 dollars, the costs are $125 to $160 per kW in the EIA report, $159 to $232 per kW in the EPA study, $145 to $370 per kW in the EEI study, and approximately $293 per kW in the Peabody report. The retrofit costs in the EIA study are in the lower range, because the costs for one or two spare modules were not included. In addition, it was assumed that small or old units, which have higher retrofit costs, would not retrofit. Spare modules for reliability of the pollution control equipment could raise the cost by 20 to 30 percent (for one spare) or 50 to 60 percent (for two spares). Since the SO_2 emissions standard specified in this legislation is on an annual basis, and not over 24 hours or less, plants could be operated when the FGD equipment was not 100 percent available and remain in compliance. Therefore, it was assumed that the utility would avoid the additional cost of redundant units. The EIA and EEI studies also included a cost for modifying boilers and electrostatic precipitators when necessary to burn low-sulfur coal, whereas the EPA and Peabody studies did not.

Table 15. Underlying Assumptions in Studies of S.3041

Assumption	EIA	ICF, Inc. (EPA)	NERA, Inc. (EEI)	Peabody Holding Co.
SO_2 8-million-ton reduction	Based on State apportionment specified in the legislation. Intrastate trading with small amount of interstate trading allowed (5 percent of each State's allocation).	Based on State apportionment specified in the legislation. Intrastate trading.	Based on State apportionment specified in the legislation. Applied to utility level for 24 utilities (3.5-million-ton reduction).	Based on State apportionment specified in the legislation. Applied to plant level.
NO_x limitation	None except as limited by current SIPs.	None except as limited by current SIPs.	None.	None.
Area of impact	31 States.	31 States.	24 utilities in 31 States.	31 States.
Phased implementation or implementation in 1 year	Phased.	Phased.	1 year.	1 year.
Utility and/or industry reduction	Utility.	Utility and industrial.	Utility.	Utility and industrial.
Utility SO_2 emissions growth offset	Yes.	Yes.	Yes.	Yes.
Industry SO_2 emissions growth offset	No.	Yes.	No.	Yes.
Cost of compliance with existing SIPs included	No.	No.	Yes.	Yes.
Growth rate in electricity demand	2.9 percent (base case).	1.5 percent, 1980-1985. 2.7 percent, 1985-2010.	Not specified.	Not specified.
FGD retrofit costs (1980 dollars)	$125 to $160 per kW.	$159 to $232 per kW.	$145 to $370 per kW (varies by utility).	12.5 mills/kWh annualized cost[a]
FGD redundancy (spares)	No.[b]	Yes.	Yes.	Yes.
Boiler modification cost for low-sulfur coal (1980 dollars)	$70 per kW.	None.	Included but not identified.	None.
ESP modification cost for low-sulfur coal	$50 per kW.	None.	Included but not identified.	None.

[a] The FGD annualized cost includes capital and operation and maintenance costs and relates to an approximate FGD capital cost of $293 per kW in 1980 dollars.

[b] It was assumed that spares would not be included, because the legislation only requires SO_2 emission levels to meet an annual standard. Therefore, outage of an FGD module would not necessarily require the plant to be shut down. If spares had been included, the cost of retrofit would be 20 to 30 percent higher for one spare or 50 to 60 percent higher for two spares.

Sources: EIA, present study; ICF, Inc., *Analysis of a Senate Emission Reduction Bill (S.3041)*, Report for EPA, February 1983; NERA (National Economic Research Associates, Inc.), *A Report on the Results from the Edison Electric Institute Study of the Impacts of the Senate Committee on the Environment and Public Works Bill on Acid Rain Legislation (S.768)*, Report for Edison Electric Institute, June 20, 1983; Peabody Holding Company, Inc., *Economic Impacts of Senate Environment and Public Works Committee Acid Rain Legislation 1983*.

Finally, when a power plant is currently not in compliance with existing State implementation plans (SIPs), the cost to come into compliance was subtracted from the cost of compliance with S.3041 in the EIA and EPA studies, since these costs would be incurred even without the new legislation. However, in the EEI and Peabody studies, these costs were included as costs of compliance with S.3041.

Comparisons

Table 16 presents the projections from the four reports. If the estimate published in the report has been modified for more direct comparison, the original value is listed in the left column under each study name, with the adjusted value on the right. For example, the EIA study reports all financial impacts in 1980 dollars. These values are inflated to 1982 dollars for comparison with the other studies.

The revenue requirements projected consist of all operating and capital costs of providing service in a particular year. In the EIA study, the amount of capacity modified each year with pollution control equipment was assumed to be evenly divided over the years 1991 to 1995, to ensure the least possible disruption of system reliability. Therefore, the revenue requirements projected for 1995 are not first-year requirements on all the capital expenditures; they are first-year requirements for one-fifth of the expenditures, second-year requirements for an additional one-fifth, and so forth.

The EEI report presents the increased revenue for the first year the legislation is in effect, assuming that all capital expenditures enter the rate base in the same year for the 24 utilities surveyed. The levelized revenue requirements for the first 5 years of operation are also presented. Therefore, to compare with the EIA projections, the 5-year levelized value, although not exactly the same, is more useful. Also, the EEI's published projections are for only 24 utilities that account for 3.5 million tons or 44 percent of the 8-million-ton reduction in SO_2 emissions. If we assume that these 24 utilities are a representative sample accounting for 44 percent of the SO_2 reduction, the total increase in revenue requirements for the 31 States would be 2.27 times the total for the 24 utilities. After this adjustment, the EEI estimate is higher than the EIA estimate, for the following reasons: (1) the amount of capacity that is projected to be retrofit with FGD is greater; (2) the capital cost of retrofits is higher, because spare modules are included; (3) the premium projected for the price of low-sulfur coal versus high-sulfur coal is higher; and (4) if a plant is not in compliance with existing SIPs, the cost of compliance is not deducted from the cost of compliance with S.3041. In addition, the intrastate trading allowed in the EIA report could lower the cost of compliance.

In the initial years of compliance with S.3041, capital expenditures for retrofits would result in a greater increase in the price of electricity than would switching to low-sulfur coal. Therefore, the projected price increases are higher for the studies with more capacity projected to be retrofit. For comparison, the percentage increases reported by EPA and EEI were converted to mills per kilowatthour. The ICF study gave a percentage increase above the 1980 residential price of electricity, and the EEI report provided utility-specific percentage increases over 1982 rates. The EIA and EPA results are average increases for the 31 States, while the range given by EEI represents the lowest and highest increases among the 24 utilities.

Annualized costs were provided in the EPA and Peabody Holding Company studies. This calculation levelizes the capital expenditures over 15 to 30 years, depending on the useful life of the equipment. An estimate of annualized capital costs for the EIA

Table 16. Comparison of Studies of the Impacts of S.3041

	Source of Estimate								
	EIA, Present Study, June 1983			ICF, Inc., Prepared for EPA, February 1983 (1982 Dollars)			NERA, Inc., Prepared for EEI, June 1983 (1982 Dollars)		Peabody Holding Company, No Date (1982 Dollars)
Impact of Legislation	(1980 Dollars)	(1982 Dollars)					3.5 million tons[a]	8.0 million tons[b]	
Electric Utilities (31-State Region)	As Reported	Adjusted		As Reported	Adjusted		As Reported	Adjusted	As Reported
Financial									
Increase in 1995 Revenue Requirements (Billion Dollars)	5.9	6.8		—	--		5.1[c] 4.0[d]	11.6[c] 9.1[d]	--
Increase in 1995 Average Electricity Prices (Percent)	--	--		2.9[e]	--		3.9-53.8[c,f] 3.9-38.0[d,f]		--
(Mills per Kilowatthour)	2.7	3.1		—	1.8[g]			2.4-33.0[c] 2.4-23.3[d]	--
Increase in 1995 Annualized Costs (Billion Dollars)									
Utility	2.6[h]	4.1[i]		2.9	--		--	--	--
Industrial	--	--		0.6	--		--	--	--
Total	2.6[h]	4.1[i]		3.5	--		--	—	7.0
Incremental Cumulative Capital Expenditures, 1983 to 1995 (Billion Dollars)									
FGD (Scrubbers)	2.8	3.2		2.6	--		--	--	--
Boiler Modification	2.1	2.4		--	--		--	—	--
Other[j]	3.7	4.3		--	--		--	--	--
Total	8.6	10.0[k]		--	--		15.3	34.8	--
Operations									
Capacity Retrofit with FGD (Gigawatts)	21.8			7.8			39.2	89.1	--
Capacity Converting to Low-Sulfur Coal (Gigawatts)	99.1			--			--	--	--
Coal Production in 1995 (Million Tons)	w/o S.3041	with S.3041	Percent change	w/o S.3041	with S.3041	Percent change			
Northern Appalachia	242	203	-16	213.0	154.8	-27	—	--	170 million tons of coal displaced in 1995; 43,000 mining jobs lost
Central Appalachia	346	439	+27	294.8	347.1	+18	--	--	
Southern Appalachia	34	31	-9	25.8	25.4	-2	--	—	
Midwest	198	111	-44	181.9	91.8	-50	—	—	
West	476	532	+12	584.6	679.6	+16	--	--	
Total	1,296	1,316	—	1,300.1	1,298.7	--	—	—	

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[a] Estimate assuming a reduction of 3.5 million tons in SO_2 emissions by 24 utilities.

[b] Estimate of 8-million-ton reduction in SO_2 emissions in the 31 States, calculated by EIA for the present comparison by multiplying the EEI figure by a factor of 2.27.

[c] Estimate for first year (1993).

[d] Estimate for 5 years (levelized, 1993-1997).

[e] Percent of 1980 residential price of electricity.

[f] Percent of 1982 rates for each utility. The range represents the lowest and highest increases among the 24 utilities.

[g] The price increase was calculated by multiplying the percent increase (2.9) by the 1980 average residential price reported in the Energy Information Administration, Monthly Energy Review.

[h] Includes operation and maintenance and fuel costs only.

[i] Includes capital, operation and maintenance, and fuel costs.

[j] Includes new transmission lines and new capacity.

[k] Total does not equal sum of components, due to independent rounding.

study was calculated for comparison purposes, using the fixed-charge factors developed by ICF for the EPA study. This annualized capital cost is added to the EIA projections for fuel and operating and maintenance expenditures in 1995 to provide an estimate of total annualized costs. It should be noted that the EIA results displayed in the column labeled "1980 Dollars" in Table 16 do not include the annualized capital cost estimates, whereas those in the column labeled "1982 Dollars" do include them. The EPA report projects the annualized costs for utilities to be highest in 1995 and then decline to $2.4 billion (1982 dollars) in 2010. The other studies did not estimate cost impacts beyond 1995. The Peabody study has higher total annualized costs because ICF estimates for FGD equipment were inflated by 25 percent to account for uncertainty in the cost of retrofitting units. In addition, the Peabody study assumed that each power plant within a given State would have to meet the same emission limit. Higher costs of compliance occur when no trading of reductions within a utility or State is allowed.

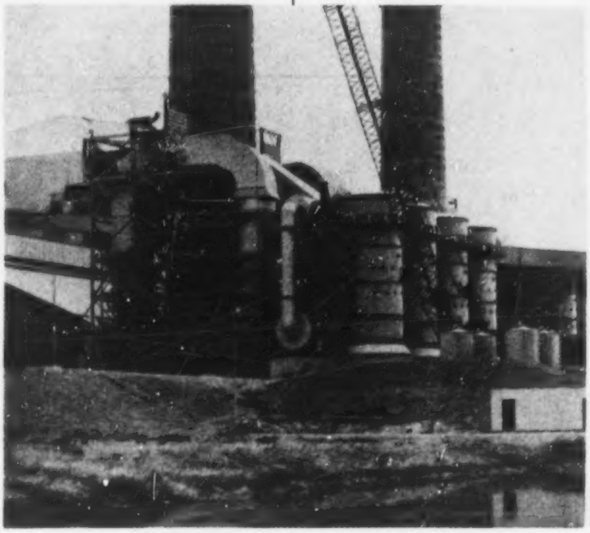
The EPA report is the only study that evaluated the impact of the legislation on the industrial sector. The projected annualized costs (in 1982 dollars) for the industrial sector are $0.6 billion in 1995, $1.2 billion in 2000, and $1.7 billion in 2010. Total annualized costs projected in the EPA report for electric utilities and industry are $3.5 billion in 1995, $3.5 billion in 2000, and $4.1 billion in 2010.

The estimates of capital expenditures will depend on the amount of capacity projected to retrofit, the cost of retrofits, and whether additional costs such as boiler and electrostatic precipitator (ESP) modifications to burn low-sulfur coal are included. The economic choice for retrofitting versus switching to low-sulfur coal depends on the time horizon used for the cost comparison, the estimated difference in delivered price of low-sulfur versus high-sulfur coal, and any additional costs for using low-sulfur coal. The EEI study has some of the highest retrofit costs and also projects the most capacity to be modified. The estimated premium for low-sulfur versus high-sulfur coal ranges from $5 to $32 per ton (1982 dollars). Several utilities surveyed reported that in the longer term (the time horizon is not specified), the costs of retrofitting with FGD would likely be lower than the costs of switching to low-sulfur coal.

The EPA report projects less retrofitting, because the 15-year levelized costs of retrofitting a plant and using higher sulfur coal were higher in most cases than the projected costs of switching to low-sulfur coal. The EIA results are between those of the other two studies. Projected capital expenditures are higher than those in the EPA report for the following reasons: (1) more capacity is projected to retrofit with FGD because of the lower capital cost estimates; (2) additional costs to modify boilers and ESPs to use low-sulfur coal are included; and (3) costs of new capacity and transmission lines to retire more of the old units are also included. The EIA study projects less capacity to retrofit than the EEI study. One factor in this difference is the lower estimated premium for low-sulfur versus high-sulfur coal. In the EIA report, the premium varies by region, ranging from $10 to $25 (1982 dollars) per ton. The Peabody report assumed that switching to low-sulfur coal would be used unless the emission standard could not be met. The premium for low-sulfur versus high-sulfur coal is assumed to be $5 per ton higher than the 1982 delivered price of low-sulfur versus high-sulfur coal.

Shifts in coal production also depend on the amount of capacity projected to retrofit with FGD equipment. Less coal production will be displaced when more retrofits are projected. EEI did not estimate the impact on the coal industry. The other studies, which all project more switching to low-sulfur coal than EEI, estimate the shift in coal production. EIA projects a displacement in 1995 of 148 million tons, mostly in Northern Appalachia, the Central West, and the Midwest. Peabody Holding Company projects a displacement of 170 million tons, and ICF projects a displacement of 149 million tons.

Appendixes



Appendix A
PROJECTED EMISSIONS OF SULFUR DIOXIDE AND NITROGEN OXIDES AND REGIONAL COAL EXPENDITURES FOR 31 EASTERN STATES

Appendix A consists of five tables. Table A1 shows projected emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x) in millions of tons per year for the utility regions in the 31 Eastern States for the years 1985, 1990, and 1995 for the base case both with and without proposed legislation S.3041, based on an annual electricity standard demand growth rate of 2.9 percent. Table A2 shows the same information as the base case without S.3041 for low electricity demand (1.9 percent annual growth rate) and high electricity demand (3.9 percent annual growth rate).

Table A3 shows projected regional utility coal expenditures in millions of dollars for the utility regions in the 31 Eastern States in 1995 for the base case both with and without proposed legislation S.3041 for five scenarios:

- Annual standard electricity demand growth rate of 2.9 percent
- 5-percent coal transportation increase with standard demand growth rate
- 9-percent coal transportation increase with standard demand growth rate
- Low electricity demand growth rate of 1.9 percent
- High electricity demand growth rate of 3.9 percent.

Tables A4 and A5 show projected regional utility fuel expenditures and operation and maintenance expenditures, respectively, in millions of dollars in 1995 for the same utility regions and scenarios as in Table A3.

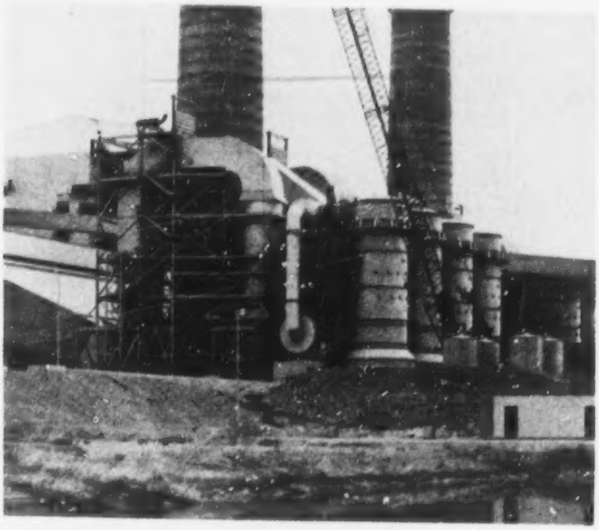


Table A1. Utility Emissions of Sulfur Dioxide (SO_2) and Nitrogen Oxides (NO_x) in the 31 States for the Base Cases, 1985-1995
(Thousand Tons per Year)

Utility		1985				1990				1995			
		Without S.3041		With S.3041		Without S.3041		With S.3041		Without S.3041		With S.3041	
Region	Name	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x
MV	Maine/Vt./N.H.	104	38	83	38	94	32	72	32	65	19	38	19
MC	Mass./Conn./R.I.	330	168	332	168	331	168	311	166	367	197	258	193
NU	N.Y., Upstate	355	129	355	129	358	132	243	132	382	159	186	160
JY	N.Y., Downstate/N.J.	323	205	333	205	347	223	328	223	409	277	238	251
WP	Pennsylvania, West	929	282	929	282	943	297	878	299	991	340	417	343
EP	Pennsylvania, East	511	164	510	164	517	172	499	172	518	173	354	173
MD	Maryland/Delaware	280	106	279	106	301	118	267	119	330	140	197	132
VD	Virginia/Wash. D.C.	178	89	173	91	245	128	175	119	274	159	170	130
NW	W. Virginia, North	675	139	469	133	787	145	482	148	709	159	251	161
SW	W. Virginia, South	191	112	191	112	189	111	187	111	280	121	183	118
CA	N. and S. Carolina	641	282	689	286	691	298	689	303	778	376	595	378
GA	Georgia	799	192	851	217	808	206	681	247	820	233	404	289
NF	Florida, North	625	179	568	180	660	207	522	207	721	248	355	249
SF	Florida, South	239	113	166	78	259	141	135	83	337	186	108	93
EK	Kentucky, East	287	53	199	53	294	62	209	63	312	93	117	92
WK	Kentucky, West	571	229	452	230	608	255	488	255	642	298	427	294
ET	Tennessee, East	240	65	240	65	237	64	237	64	195	51	103	53
WT	Tennessee, West	495	103	446	103	487	102	453	106	529	114	182	117
AM	Alabama/Mississippi	789	240	787	241	838	266	636	267	891	331	427	335
ON	Ohio, North	882	153	646	162	908	169	649	159	952	158	401	166
OC	Ohio, Central	229	57	171	57	336	63	179	63	240	69	97	70
OS	Ohio, South	1,101	216	810	218	1,105	216	806	217	1,032	225	368	231
MI	Michigan	566	182	574	182	562	190	547	188	657	252	497	249
IL	Illinois	1,156	327	909	327	1,050	274	818	275	1,188	347	495	368
IN	Indiana	1,438	319	1,047	323	1,466	335	1,070	338	1,533	394	532	396
WI	Wisconsin	691	138	504	148	710	154	436	159	730	170	204	188
MN	Minnesota	187	110	185	110	199	137	174	135	232	181	148	176
AO	Arkansas/Louisiana[a]	353	377	353	377	459	418	263	409	520	501	294	482
IA	Iowa	243	108	215	109	244	119	215	120	265	130	138	123
MO	Missouri	1,163	181	610	184	1,125	172	646	173	1,290	204	282	223
Total		16,578	5,046	14,089	5,069	16,945	5,354	13,257	5,350	18,113	6,304	8,290	6,243

[a] Includes Oklahoma.

Source: Energy Information Administration, U.S. Department of Energy, National Coal Model (NCM), 1983.

Table A2. Utility Emissions of Sulfur Dioxide (SO_2) and Nitrogen Oxides (NO_x) Without S.3041 in the 31 States for Low and High Electricity Demand
(Thousand Tons per Year)

Utility Region	Name	Low Demand[a]						High Demand[b]					
		1985		1990		1995		1985		1990		1995	
		SO_2	NO_x	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x
MV	Maine/Vt./N.H.	104	38	[illegible]	25	30	12	107	40	104	39	96	33
MC	Mass./Conn./R.I.	316	157	300	144	324	165	342	177	356	187	402	220
NU	N.Y., Upstate	339	121	334	124	339	137	360	134	370	148	402	180
JY	N.Y., Downstate/N.J.	350	188	279	172	319	210	377	245	431	286	508	363
WP	Pennsylvania, West	921	271	939	291	965	312	932	286	952	312	1,008	367
EP	Pennsylvania, East	493	148	425	119	427	122	514	169	519	178	543	198
MD	Maryland/Delaware	276	104	294	113	293	110	277	105	332	132	354	157
VD	Virginia/Wash. D.C.	135	74	191	101	196	123	206	107	373	147	381	169
NW	W. Virginia, North	668	120	721	134	752	146	728	140	768	160	808	165
SW	W. Virginia, South	191	112	180	106	189	111	190	112	188	110	198	120
CA	N. and S. Carolina	438	263	624	255	661	318	654	302	748	338	871	434
GA	Georgia	778	179	780	182	793	198	829	203	815	228	871	272
NF	Florida, North	608	170	621	186	650	213	640	188	692	224	765	273
SF	Florida, South	218	103	211	119	268	149	261	123	304	164	382	217
EK	Kentucky, East	282	51	282	53	296	64	287	54	307	63	332	100
WK	Kentucky, West	550	220	554	217	606	261	575	338	615	278	708	336
ET	Tennessee, East	240	65	218	59	123	35	234	65	270	74	253	71
WT	Tennessee, West	500	104	487	101	473	99	551	119	548	118	577	132
AM	Alabama/Mississippi	736	209	774	226	804	255	793	246	858	287	952	389
ON	Ohio, North	915	148	923	149	937	168	847	162	895	169	988	172
OM	Ohio, Central	228	56	234	60	237	63	230	50	242	68	319	97
OS	Ohio, South	1,047	191	930	178	1,035	216	1,103	217	1,120	225	1,086	251
MI	Michigan	551	164	517	153	577	191	619	220	650	244	723	312
IL	Illinois	1,108	301	887	223	1,072	273	1,194	350	1,156	327	1,310	431
IN	Indiana	1,412	304	1,402	293	1,455	327	1,458	331	1,497	363	1,554	421
WI	Wisconsin	673	131	692	141	705	147	703	144	727	165	753	190
MN	Minnesota	185	102	191	119	212	151	189	118	281	144	233	195
AO	Arkansas/Louisiana[c]	353	356	433	370	494	421	353	399	450	472	525	594
IA	Iowa	268	103	242	105	333	115	233	116	238	129	260	149
MO	Missouri	1,101	172	994	153	1,139	176	1,199	191	1,237	199	1,366	233
Total		16,116	4,733	15,671	4,671	16,720	5,278	16,974	5,359	17,851	5,990	19,440	7,253

[a] Low demand has an average annual growth rate in electricity demand of 1.9 percent.
[b] High demand has an average annual growth rate in electricity demand of 3.9 percent.
[c] Includes Oklahoma.
Source: Energy Information Administration, U.S. Department of Energy, National Coal Model (NCM), 1983.

Table A3. Utility Regional Coal Expenditures in the 31 States, 1995
(Million 1980 Dollars)

Utility		Base Case		Transportation Cost[a]				Electricity Demand			
				5%		9%		Low Demand		High Demand	
Region	Name	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041
NV	Maine/Vt./N.H.	83	80	105	103	130	128	64	61	107	106
MC	Mass./Conn./R.I.	272	310	340	367	428	460	271	286	273	443
NU	N.Y., Upstate	503	755	608	772	832	837	549	573	615	870
JT	N.Y., Downstate/N.J.	696	866	810	1,054	959	1,211	691	812	696	1,160
WP	Pennsylvania, West	1,476	1,536	1,648	1,739	1,866	1,961	1,342	1,367	1,546	1,620
EP	Pennsylvania, East	543	552	619	637	718	773	471	479	571	585
MD	Maryland/Delaware	460	480	527	574	619	669	435	455	462	686
VD	Virginia/Wash. D.C.	500	573	593	675	711	805	461	523	501	864
NW	W. Virginia, North	674	769	767	821	645	633	618	713	693	729
SW	W. Virginia, South	553	546	619	567	697	655	498	503	549	556
CA	N. and S. Carolina	1,892	1,953	2,274	2,392	2,758	2,952	1,636	1,705	2,150	2,217
GA	Georgia	1,116	1,447	1,280	1,712	1,507	2,016	896	1,368	1,331	1,463
NF	Florida, North	1,112	1,124	1,393	1,447	1,726	1,883	1,063	1,111	1,125	1,516
SF	Florida, South	281	290	353	368	438	473	273	214	282	244
EK	Kentucky, East	449	468	503	534	625	620	285	302	487	496
WK	Kentucky, West	1,362	1,373	1,528	1,560	1,673	1,823	1,146	1,129	1,581	1,719
ET	Tennessee, East	326	227	253	256	289	293	147	149	313	317
WT	Tennessee, West	445	519	500	508	549	594	382	437	499	560
AM	Alabama/Mississippi	1,500	1,600	1,709	1,896	1,997	2,144	1,181	1,337	1,587	1,724
ON	Ohio, North	683	705	797	838	947	939	641	678	782	738
OM	Ohio, Central	255	275	288	311	324	355	238	258	327	373
OS	Ohio, South	951	1,012	1,070	1,207	1.211	1,391	895	882	1,095	1,141
MI	Michigan	1,281	1,262	1,566	1,578	1,915	1,967	1,069	1,118	1,381	1,411
IL	Illinois	1,534	1,604	1,730	1,846	1,958	1,947	1,147	1,270	1,798	2,001
IN	Indiana	1,808	1,934	2,056	2,265	2,361	2,646	1,409	1,509	1,902	2,032
WI	Wisconsin	783	807	944	1.127	1,194	1,385	678	794	852	815
MN	Minnesota	616	629	885	884	1,169	1,183	517	508	653	723
AO	Arkansas/Louisiana[b]	1,918	2,241	2,674	3,098	3,654	2,498	1,899	2,198	1,927	2,241
IA	Iowa	519	498	708	744	852	894	437	421	574	503
MO	Missouri	851	959	976	1,056	1,128	1,169	715	794	983	1,135
Total		25,422	27,430	30,195	33,007	35,872	37,232	22,054	23,939	27,562	30,984

[a] Compounded annually.

[b] Includes Oklahoma.

Source: Energy Information Administration, U.S. Department of Energy, National Coal Model (NCM), 1983.

Table A4. Utility Regional Fuel Expenditures in the 31 States, 1995
(Million 1980 Dollars)

Utility Region	Name	Base Case		Transportation Cost[a]				Electricity Demand			
				5%		9%		Low Demand		High Demand	
		Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041
MV	Maine/Vt./N.H.	195	192	217	214	242	240	91	85	446	448
MC	Mass./Conn./R.I.	3,642	3,688	3,709	3,767	3,797	3,867	2,685	2,703	4,979	5,351
NU	N.Y., Upstate	2,512	2,691	2,617	2,787	2,761	2,976	1,470	1,410	3,789	4,060
JY	N.Y., Downstate/N.J.	3,642	4,352	3,756	4,585	3,905	4,701	2,231	2,478	5,696	6,440
WP	Pennsylvania, West	1,711	1,771	1,883	1,974	2,102	2,200	1,428	1,452	2,400	2,482
EP	Pennsylvania, East	1,724	1,733	1,800	1,819	1,899	1,960	831	839	2,476	3,094
MD	Maryland/Delaware	1,741	1,835	1,808	1,921	1,900	2,017	1,010	1,030	2,773	2,981
VD	Virginia/Wash. D.C.	2,076	2,323	2,169	2,426	2,289	2,553	1,129	1,223	3,858	3,823
WN	W. Virginia, North	697	732	790	844	668	656	640	735	797	820
SW	W. Virginia, South	593	586	639	607	737	695	532	537	595	602
CA	N. and S. Carolina	3,305	3,479	3,688	3,920	4,162	4,476	1,776	1,845	4,764	5,431
GA	Georgia	1,188	2,112	1,352	2,384	1,580	2,609	946	1,501	1,600	2,743
NF	Florida, North	2,387	2,406	2,668	2,728	3,082	3,103	1,634	1,603	3,523	4,199
SF	Florida, South	3,243	1,685	3,315	1,756	3,399	1,865	2,436	573	4,303	3,541
EK	Kentucky, East	499	518	553	584	675	669	328	345	544	554
WK	Kentucky, West	1,497	1,508	1,663	1,694	1,807	1,957	1,262	1,245	1,737	1,875
ET	Tennessee, East	240	240	267	270	302	307	148	158	614	628
WT	Tennessee, West	1,023	1,147	1,078	1,216	1,132	1,222	522	577	2,114	2,175
AM	Alabama/Mississippi	2,035	2,224	2,244	2,518	2,532	2,804	1,366	1,522	3,590	4,146
ON	Ohio, North	863	859	979	1,004	1,128	1,108	692	730	1,335	1,371
OM	Ohio, Central	947	992	980	1,028	1,016	1,071	696	716	2,561	2,987
OS	Ohio, South	1,002	1,063	1,122	1,258	1,262	1,442	940	926	1,204	1,290
MI	Michigan	1,701	1,763	2,067	2,078	2,415	2,467	1,073	1,113	3,336	3,185
IL	Illinois	1,768	1,918	1,964	2,080	2,192	2,181	1,348	1,471	2,945	3,169
IN	Indiana	1,948	2,089	2,196	2,419	2,501	2,801	1,529	1,629	2,587	2,743
WI	Wisconsin	1,127	1,283	1,288	1,688	1,539	2,008	757	873	2,137	2,120
MN	Minnesota	788	801	1,057	1,056	1,341	1,364	581	572	1,121	1,444
AO	Arkansas/Louisiana[b]	5,486	5,865	6,242	6,963	7,222	7,963	3,751	4,073	7,567	7,935
IA	Iowa	630	609	811	855	964	1,006	533	517	953	831
MO	Missouri	1,008	1,116	1,133	1,213	1,285	1,326	847	926	1,275	1,440
	Total	51,299	53,580	56,075	59,656	61,756	65,702	35,212	35,479	77,621	83,932

[a] Compounded annually.
[b] Includes Oklahoma.
Source: Energy Information Administration, U.S. Department of Energy, National Coal Model (NCM), 1983.

Table A5. Utility Regional Operation and Maintenance Expenditures in the 31 States, 1995
(Million 1980 Dollars)

Utility		Base Case		Transportation Cost[a]				Electricity Demand			
				5%		9%		Low Demand		High Demand	
Region	Name	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041	Without S.3041	With S.3041
MV	Maine/Vt./N.H.	352	354	352	354	353	354	330	321	363	367
MC	Mass./Conn./R.I.	489	490	489	489	489	490	465	465	507	508
NU	N.Y., Upstate	367	368	370	370	370	373	353	352	392	397
JY	N.Y., Downstate/N.J.	729	710	729	709	729	710	687	686	782	734
WP	Pennsylvania, West	404	419	434	419	404	430	368	386	420	432
EP	Pennsylvania, East	661	664	661	665	662	683	628	635	680	712
MD	Maryland/Delaware	227	224	227	225	227	225	209	212	240	250
VD	Virginia/Wash. D.C.	370	357	370	359	370	359	345	343	392	387
NW	W. Virginia, North	88	134	88	133	91	131	77	117	91	136
SW	W. Virginia, South	75	73	75	61	75	61	62	64	74	75
CA	N. and S. Carolina	1,034	1,044	1,034	1,046	1,034	1,043	980	1,002	1,069	1,106
GA	Georgia	410	500	410	500	410	503	374	474	454	532
NF	Florida, North	237	247	237	248	242	252	211	227	255	270
SF	Florida, South	358	302	358	302	363	302	335	278	379	330
EK	Kentucky, East	79	84	79	84	83	84	43	46	88	93
WK	Kentucky, West	252	271	253	284	246	284	201	194	278	303
ET	Tennessee, East	515	520	515	520	515	528	483	498	527	542
WT	Tennessee, West	89	104	89	104	97	137	77	74	101	123
AM	Alabama/Mississippi	957	956	964	950	964	979	861	902	1,015	996
ON	Ohio, North	337	347	337	373	337	379	331	330	348	391
OM	Ohio, Central	66	67	66	67	66	67	58	60	88	96
OS	Ohio, South	240	297	240	301	242	305	234	278	273	311
MI	Michigan	582	599	582	596	590	597	540	553	623	634
IL	Illinois	1,182	1,212	1,190	1,301	1,213	1,354	1,117	1,130	1,242	1,280
IN	Indiana	441	476	450	484	456	436	361	406	471	500
WI	Wisconsin	229	233	230	237	232	255	204	219	242	243
MN	Minnesota	260	265	263	271	266	286	237	230	270	276
AO	Arkansas/Louisiana[b]	657	643	666	645	666	677	613	590	732	708
IA	Iowa	119	129	122	130	133	144	101	116	129	134
MO	Missouri	210	265	213	314	211	320	188	237	241	296
Total		12,026	12,362	12,062	12,557	12,136	12,797	11,071	11,425	12,774	13,162

[a] Compounded annually.

[b] Includes Oklahoma.

Source: Energy Information Administration, U.S. Department of Energy, National Coal Model (NCM), 1982.

Appendix B

PERCENTAGE ESTIMATE OF THE 8-MILLION-TON REDUCTION OF THE NATURAL AND MAN-PRODUCED SO_2 AND NO_x EMISSIONS IN THE 31 EASTERN STATES

Sulfur dioxide (SO_2) and nitrogen oxide (NO_x) are emitted both by natural and man-made sources. The 1980 SO_2 and NO_x man-produced emissions for the 31 eastern States are estimated to have been 21.9 and 14.0 million tons, respectively.[1]

In the eastern United States, it is believed that only about 10 percent of the total SO_2 emissions are naturally produced. Further, it is estimated that 5 to 25 percent of the total NO_x emissions are naturally produced.[2]

Therefore, the 8-million-ton reduction of SO_2 specified in S.3041 as a percent of the total (natural and man-produced) SO_2 and NO_x emissions in the 31 eastern States is estimated as follows:

$$\begin{array}{c}SO_2 \text{ Percent Reduction} \\ \text{(8 million tons)}\end{array} = \frac{(8)}{(21.9/0.90) + [(14.0/0.75) \text{ or } (14.0/0.95)]} \times 100 \quad .^3$$

Thus the total natural and man-produced SO_2 and NO_x emissions in the 31 eastern States are reduced approximately 20 percent (18.6 percent to 20.5 percent) as a result of the 8-million-ton reduction called for in S.3041.

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[1] United States-Canada, Memorandum of Intent on Transboundary Air Pollution, Work Group 3B, Emissions, Costs and Engineering Assessment, Report No. 3B Final (June 15, 1982), Table B.2.1, p. 46, and Table B.2.3, p. 48.

[2] Logan, Jennifer A., "Nitrogen Oxides in the Troposphere: Global and Regional Budgets," Center for Earth and Planetary Physics (Harvard University, December 1982). (Submitted for publication to Journal of Geophysical Research.)

[3] Divide by 0.75 or 0.95, depending on whether naturally produced NO_x is assumed to be 25 or 5 percent of the total NO_x emissions.

Appendix C
THE PRIVATELY OWNED ELECTRIC UTILITIES IN THE UNITED STATES: A REVIEW OF THE FINANCIAL AND OPERATIONAL DEVELOPMENTS DURING 1981[1]

Introduction

Comprehensive financial and operating data covering the Classes A and B privately owned electric utilities are published annually in the Statistics of Privately Owned Electric Utilities in the United States by the Energy Information Administration.[2] This publication includes 1981 data from 204 Classes A and B utilities representing nearly 100 percent of the privately owned sector of the electric light and power industry operating within the United States. Financial data include balance sheets, income and retained earning statements, and statements of changes in financial position. Operational data include additions/deletions to nameplate generating capacity, electric energy account detailing electric power generation by source, details of operation and maintenance expenses and other details. In addition, these data are also used to derive useful relationships and parameters that are of interest to analysts in the electric utility industry.

This appendix highlights the financial and operational developments of the privately owned electric utilities during the year 1981. It uses data supplied by the privately owned utilities in a pre-specified format based on the Federal Energy Regulatory Commission's Uniform System of Accounts.[3]

The 1981 Financial Year

The data for 1981 reveal a significant improvement in the overall financial results and performance of the privately owned electric utilities. As shown in Table C1, their net income increased from $10.7 billion in 1980 to $12.7 billion in 1981, an annual increase of 19.5 percent. In addition, they raised a total of $23.3 billion from the domestic capital markets by sale of long- and short-term debts and stocks. These funds, inclusive of the noncash credit accruals and funds from other sources, total $47.8 billion. They were used primarily to support new plant construction activities, to retire securities and to liquidate outstanding debts, and to pay dividends to holders of common or preferred stocks. More specifically, for the year 1981, aggregate investment activities of the group absorbed $28.1 billion in plant and construction expenditures.[4] This represents about 8.1 percent of the total

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[1] Written by Suraj P. Kanhouwa, Financial Economist, Data Analysis and Forecasting Branch, Electric Power Division, EIA.

[2] Class A utilities are those having an annual electric operating revenue of $2.5 million or more. Class B utilities are those with an electric operating revenue of $1.0 million or more, but less than $2.5 million.

[3] These data include the accounts and operations of the individual companies only. Accordingly, the accounts of the parent and subsidiary companies are not included. A further caveat is that no attempt is made to synthesize available data from alternative sources. Additional qualifiers to the data are listed in the "Preface" to Statistics of Privately Owned Electric Utilities in the United States, 1981 (Washington, D.C., June 1983).

[4] Includes gross additions to nuclear fuel.

Table C1. Comparison of Selected Financial Statistics of the Classes A and B Privately Owned Electric Utilities, 1981 and 1980

	1981 (Billion Dollars)	1980 (Billion Dollars)	Percent Change[a]
Income Statement[b]			
Electric Utility Operating Revenues	102.3	87.1	17.5
Gas and Other Utility Operating Revenues	15.8	13.7	15.7
Total Utility Operating Revenues[c]	118.1	100.8	17.3
Electric Utility Operating Expenses	86.0	73.4	17.2
Gas and Other Utility Operating Expenses	15.2	13.0	16.2
Total Utility Operating Expenses[d]	101.2	86.4	17.0
All Utility Operating Income	17.0	14.4	18.5
Net Other Income and Deductions[e]	4.7	3.9	20.3
Net Interest Charges	9.0	7.6	18.4
Net Income[f]	12.7	10.7	19.5
Sources of Funds[b]			
Net Income	12.7	10.7	19.5
Non-Cash Credits[g]	8.3	7.4	11.5
Total Funds from Operations	21.0	18.1	16.1
Funds from Outside Sources[h]	23.3	22.0	5.8
Other	3.5	3.2	11.6
Total Sources of Funds	47.8	43.3	10.5
Application of Funds			
Construction and Plant Expenditures	28.1	26.4	6.6
Dividends	9.8	8.6	14.4
Retirement of Securities	5.9	4.8	23.9
Other	3.9	3.5	11.8
Total Application of Funds	47.8	43.3	10.5

[a] Percent change has been computed by using data before rounding.

[b] For additional data and detail, see Tables 3 and 19 in the Statistics of Privately Owned Electric Utilities in the United States--1981 Annual.

[c] Includes income from electric, gas and other operations.

[d] Includes operating expenses, electric, gas and other operations.

[e] Includes an adjustment covering allowance for borrowed funds used during construction credit.

[f] To arrive at net income, additional adjustments are made to include net interest charges and extraordinary items after taxes. Net interest charges in 1981 amounted to $9.0 billion. Extraordinary items (after taxes) contributed $44.7 million.

[g] Includes depreciation and depletion, amortization, net provision for deferral or future income taxes, investment tax credit adjustments, etc., and an adjustment for allowance for funds used during construction.

[h] Includes funds obtained from domestic capital markets by sale of debts or stocks.

Note: Totals may not equal sum of components due to independent rounding.

Source: Federal Energy Regulatory Commission Form 1 and predecessor systems.

domestic nonresidential fixed business investment.[5] Dividend payments absorbed another $9.8 billion, up from $8.6 billion in the preceding year.

Industry analysts generally agree that the significant growth in earnings and its associated impact on the financial health of the privately owned utilities during 1981 stem primarily from the efforts of the regulators to strengthen their financial position through favorable rate decisions. In addition, other factors contributing to this development include moderation of the fuel price increases, realization of the beneficial impacts of changes in tax laws, modifications in accounting procedures and a lower-than-projected increase in peakload demand.

Improvements in profitability enabled the privately owned electric utilities to maintain growth in asset acquisitions during 1981. Table C2 shows that the total assets of this group increased by 10 percent to $286.0 billion, up from $260.0 billion in 1980. Nearly 78 percent of the increase in assets or $20.3 billion were absorbed by the increase in total utility plant, $2.5 billion in current assets, and the balance of $3.2 billion by other investments and deferred debits. The countervailing changes on the liability side are concentrated principally in additions to the proprietary capital ($9.5 billion) and long-term debt ($10.2 billion).[6] Continuing significant additions to "deferred credits" result from liberalized tax laws affecting depreciation and new investments and the "timing differences" between book and tax accounting.

While the overall results indicate an improvement over the group's performance in 1980, the state of the economy during 1981 tended to dampen both the demand for electric power and consequently industry profitability. Important economic factors that influenced demand included the continuing inflation in 1981, high interest rates, and the magnitude of recessionary forces during the year under review.

Significant improvements in industry profitability did not, however, materially alter the quality of utilities' earnings. The principal factor contributing to this development stems from the regulatory environment in which the utilities operate. This is briefly discussed below.

Utilities are obligated to meet the requirements of future demand growth by making timely additions to installed nameplate capacity while simultaneously maintaining overall system reliability and adequacy. Given the fact that it takes several years to plan and complete a new generating facility, commitment of large financial outlays becomes necessary before a new plant can be placed in operational service and start producing revenues. Since the early 1970's, however, construction costs have escalated rapidly and the leadtimes necessary for completion of new plants have lengthened. As a result, outstanding utility investments in construction work in progress (CWIP) have been increasing over time. For the decade ending in 1981, these investments in CWIP have increased at an average annual rate of 17.2 percent from $16.6 billion in 1972 to $69.4 billion in 1981. This amount represents over 23 percent of

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[5] Total new nonresidential fixed business investment for the domestic economy was $346.1 billion in 1981.

[6] Proprietary capital includes common and other paid-in capital, preferred stock, retained earnings, and unappropriated/undistributed earnings in subsidiaries.

Table C2. A Comparison of Selected Balance Sheet Items of Classes A and B Electric Utilities, 1981 and 1980

	1981 (Billion Dollars)	1980 (Billion Dollars)	Percent Change[a]
Assets[b]			
Total Electric Utility Plant[c]	285.4	260.3	9.7
Electric Utility Depreciation, Depletion and Amortization	58.2	52.7	10.3
Net Electric Utility Plant	227.2	207.5	9.5
Net Nuclear Fuel	4.0	3.9	1.4
Net Other Utility Plant	10.8	10.3	5.1
Total All Utility Plant	242.0	221.7	9.2
Total Other Property and Investment	7.9	6.5	21.4
Total Current and Accrued Assets	28.7	26.2	9.7
Total Deferred Debits	7.3	5.5	32.3
Total Assets and Other Debits	286.0	260.0	10.0
Liabilities[b]			
Total Proprietary Capital			
Retained Earnings	25.0	22.7	10.0
Equity	89.0	81.7	9.4
Total Long-Term Debt	115.5	105.3	9.7
Total Current and Accrued Liablities	28.4	26.3	7.9
Total Deferred Credits and Reserves	28.1	23.9	17.6
Total Liabilities and Other Credits	286.0	260.0	10.0

[a] Percent change has been computed by using data before rounding.

[b] For additional data and detail, see Table 12 in the Statistics of Privately Owned Electric Utilities in the United States--1981 Annual.

[c] Includes construction work in progress amounting to $69.4 billion and $60.4 billion respectively.

Note: Totals may not add to sum of components due to independent rounding.

Source: Federal Energy Regulatory Commission Form 1 and predecessor systems.

the aggregate investment in electric utility plant in 1981.[7] These data are shown in Table C3.

Historically, CWIP has not been included in the utility rate base on the assumption that these investments do not affect the cost of providing service to the current customers and therefore could not be included. Yet, to the extent that these investments are financed during the construction phase from internal and external sources

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[7] Includes electric utility plant investments, nuclear fuel, and electric construction work in progress.

Table C3. Electric Utility Plant Construction Work in Progress and Total Electric Utility Plant Relationship, 1972-1981
(Billions of Dollars)

Year	CWIP[a]	Total Electric Utility Plant	CWIP/ Total Electric Utility Plant (Percent)[b]
1972	16.62	116.64	14.2
1973	20.25	130.83	15.5
1974	22.84	146.00	15.6
1975	26.32	160.71	16.4
1976	31.72	177.57	17.9
1977	36.48	196.81	18.5
1978	42.48	218.00	19.5
1979	53.99	242.31	22.3
1980	60.44	266.92	22.6
1981	69.44	292.74	23.7

[a] Data from 1975 to 1981 include environmental construction work in progress in the CWIP.

[b] Percentage change computed before rounding.

Source: Federal Energy Regulatory Commission Form 1 and predecessor systems.

(i.e., from sale of stocks, debts, bonds or retained earnings), dividend and interest payments need to be made irrespective of the income-producing status of such projects.

The need to compensate those who invest in utilities during the construction phase of the facilities poses a problem for the utilities since the balance of the CWIP account is not generally included in the rate base until the new facilities are completed and placed in useful service. More recently, the treatment of CWIP by the regulatory commissions and its impact on the financial capability of the utilities to fund new/ongoing construction expenditures have been extensively discussed and debated.[8] While new legislative initiatives are still being considered, the utilities are recompensed for investments absorbed by the CWIP in the following manner.

An amount equal to the net cost of borrowed funds and a reasonable rate on other funds (used for construction purposes from internal sources) is added to the income or the revenues of the utilities. As a percentage of net utility income, this non-cash accrual (known as "allowance for funds used during construction" or AFUDC) has become significant since the 1970's. In 1981, for example, AFUDC contributed

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[8] Even now, not all the public utility commissions permit the inclusion of CWIP in the rate base.

$5.3 billion or 41.3 percent of net utility income of $12.7 billion. Data for the period 1972 to 1981 are shown in Table C4. Industry analysts contend that these developments dilute the quality of electric utilities' earnings and add to the cost of funds from external sources.

Partly as a result of this development but principally due to the high interest rates that prevailed during the year under review, the average cost of debt to the utilities has continued moving upward. The need to borrow large amounts of fresh capital and the requirement to rollover maturing debt contracted at considerably lower costs have pushed the average embedded borrowing cost from 8.6 percent in 1980 to 9.3 percent in 1981.[9] (See Table C5.) In fact, total interest charges increased from $9.6 billion in 1980 to $11.5 billion in 1981, reflecting an annual increase of 19.5 percent. In contrast, the total utility debt consisting of short- and long-term obligations increased only by 9.5 percent, up from $112.2 billion in 1980 to $122.8 billion in 1981. Based on the current projections of the long-term investment requirements of the privately owned utilities, this trend to finance future investments at rates higher than those that prevailed during the 1960's and the early 1970's is likely to continue in the near term. As a result, the capital cost component of electric power generation would also keep moving upward.

Notwithstanding the large funds raised from external sources, capitalization ratios have remained nearly the same as in the past. For 1981 these are: debt, 50.3 percent; preferred stock, 11.6 percent; common stock, 26.7 percent; and retained earnings, 10.9 percent.[10]

The disposition of net income of the privately owned utilities is shown in Table C6. Of the $12.7 billion in net income, dividend payments on preferred stock absorbed $2.2 billion. This yielded an average dividend rate of 8.7 percent in comparison with an 8.4 percent rate in 1980. The remainder, i.e., $10.5 billion, represents income available for common equity. Based on the average dollar value of equity outstanding during 1981, this amount translates into a 12.5-percent realized average rate of return on equity. This is significantly better than the 11.5-percent rate of return achieved during 1980 and during the decade that ended in 1981. This improvement permitted the utilities to lower the payout ratio from the unprecedented high level of 77.6 percent in 1980 to 74.4 percent during 1981.[11] As shown in Table C6, this move increased the residual value of income retained in business to $2.7 billion, up from $1.9 billion in 1980.

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[9] Declining interest coverage ratios are another contributory factor. A complete discussion of this aspect is not provided in this analysis. See Table C5.

[10] Corresponding percentages for the decade ending in 1981 are: 51.4, 12.2, 25.0 and 11.0.

[11] Payout ratio may be defined as the amount paid on common stocks divided by the income available for common equity.

Table C4. Allowance for Funds Used During Construction as Percent of Net Income, 1972-1981
(Billions of Dollars)

Year	Net Income Reported	Allowance for Funds Used During Construction (AFUDC)	AFUDC as Percent of Net Income[a]
1972	4.42	1.07	24.2
1973	4.99	1.24	24.8
1974	5.30	1.53	28.9
1975	6.20	1.64	26.5
1976	7.19	1.85	25.8
1977	8.00	2.26	28.2
1978	8.72	2.75	31.5
1979	9.48	3.60	38.0
1980	10.67	4.40	41.2
1981	12.73	5.25	41.3

[a] Percentage change computed before rounding.

Source: Federal Energy Regulatory Commission Form 1 and predecessor systems.

Table C5. Short and Long-Term Debt of Classes A and B Electric Utilities, 1972-1981
(Billions of Dollars)

Year	Short-term Debt	Long-term Debt	Total Debt[a]	Total Interest Charges Paid During the Year[b]	Average Debt Cost (Percent per Year)[c]
1972	2.97	51.53	54.50	3.00	5.51
1973	4.06	56.67	60.73	3.52	5.80
1974	6.68	64.50	71.13	4.50	6.32
1975	3.95	70.82	74.77	5.11	6.83
1976	3.09	76.21	79.30	5.49	6.93
1977	3.32	82.18	85.50	5.97	6.99
1978	3.55	88.26	91.81	6.73	7.33
1979	6.65	95.66	102.31	7.80	7.63
1980	6.90	105.26	112.16	9.59	8.55
1981	7.34	115.45	122.79	11.48	9.35

[a] Includes short-term debt.

[b] Data for 1977-1981 exclude capitalized interest during construction.

[c] Average debt cost equals total interest charges divided by total debt.

Source: Federal Energy Regulatory Commission Form 1 and predecessor systems.

Table C6. Disposition of Net Income for Classes A and B Privately Owned Electric Utilities as of December 31, 1980 and 1981 (Thousands of Dollars)

Item	1981	1980
Net Income	12,729,961	10,675,977
Less: Preferred Stock Dividends Declared	2,254,848	2,046,357
Income Available for Common Equity	10,475,113	8,629,620
Less: Common Dividends Declared	7,798,354	6,700,773
Net Income Retained in Business	2,676,759	1,928,847

Note: Totals may not equal sum of components due to independent rounding.

Source: Federal Energy Regulatory Commission Form 1 and predecessor systems.

The 1981 Operational Year

Total installed nameplate capacity of the privately owned electric utilities increased by 0.8 percent, from 476,288 MW in 1980 to 480,325 MW in 1981. This increase in capacity is principally concentrated in new coal-fired and nuclear-powered plants having come on line during the year under review.[12]

Total net electric generation in 1981 increased only marginally, by 0.5 percent, to 1.793 trillion kWh, up from 1.785 trillion kWh in 1980. Coal-, oil-, and gas-fired steam generating plants were the source of 83.4 percent of the generation, followed by 13.2 percent from nuclear generation and the remainder from hydroelectric and gas turbine or internal combustion sources.

Nuclear power was the only prime mover for which generation increased during 1981. Decline in generation from other sources represents an effort to use the cheapest generating capacity to meet demand.

Privately owned electric utilities were responsible for 77.8 percent of net generation in the United States during 1981. This share has remained stable, averaging 77.9 percent for the period 1972 through 1981.

Power purchases by this group increased by 6.3 percent in 1981, up from 280.2 million kWh in 1980 to 297.8 million in 1981. While absolute purchases have increased annually, their share in relation to total net generation has moved within a narrow range. Purchases have ranged from a low of 14.2 percent in 1977 to a high of 16.7 percent in 1981. Similarly, interchanges and transmission (wheeling) as a share of net generation have ranged from 1.3 percent in 1972 to 2.4 percent in 1981.

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[12] Aggregate capacity data for 1981 are provisional and subject to revision.

Disposition of power has also remained fairly stable. In 1981, 77.0 percent of the energy generated and received was sold to end-use customers and 16.5 percent sold to wholesale customers and other utilities. Transmission losses account for nearly 6.2 percent.

The number of customers served increased 1.8 percent, from an average of 70.6 million in 1980 to an average of 71.9 million in 1981. Of these, nearly 88.2 percent or 63.4 million were residential customers, followed by 7.8 million commercial and industrial customers, accounting for 10.9 percent of the total. The remaining 0.9 percent of the customers are small, miscellaneous groups such as the railroads, interdepartmental customers, and others.

Average annual energy use per residential customer declined by about 3 percent in 1981 to 8,277 kWh, down from 8,531 kWh in 1980. Average kWh costs to customers, however, increased from 5.36 cents in 1980 to 6.20 cents in 1981, an increase of 15.7 percent.

In the commercial sector, average annual use increased by a modest 0.6 percent from 53,589 kWh in 1980 to 53,927 kWh in 1981. Per-kWh prices charged this group in 1981 reflect an increase of 14.8 percent, up from 5.48 cents in 1980 to 6.29 cents in 1981.

Total sales to industrial customers increased by 1.2 percent, from 628.7 million kWh in 1980 to 636.3 million kWh in 1981. The average annual sales to this category declined from 1.68 million kWh in 1980 to 1.67 million kWh in 1981. Average annual cost per customer, however, increased by 15.2 percent, from $61,922 in 1980 to $71,361 in 1981, reflecting a corresponding increase in the per-kWh price, from 3.67 cents to 4.26 cents. These and other significant statistical operating data of the privately owned electric utilities are shown in Table C7.

Summary

In conclusion, the financial health of the privately owned electric utilities improved significantly during the year under review. Improvements in profitability led to corresponding improvements in the rates of return on equity and enabled the utilities to obtain better terms in selling bonds and stocks than in the recent past. However, the additions to capacity were not matched by anticipated increases in the demand for power, due to the magnitude of recessionary forces in the economy. Uncertainties associated with projecting future demand patterns, and the requirement to commit massive financial resources to assure an adequate and reliable supply of power may continue to pose a major challenge to the utilities for most of this decade.

Table C7. Comparison of Selected Operating Statistics of the Classes A and B Privately Owned Electric Utilities, 1981 and 1980

Item	1981	1980
Installed Generating Capacity, Total Generating Plants (millions of kWh)[a]	480,325	476,288
Electric Energy Account (millions of kWh)		
Net Generation	1,793.2	1,784.9
Purchases	297.8	280.2
Net Interchanges	44.6	34.1
Net Wheeling	-1.5	-1.0
Less Energy Used for Pumped Storage	-12.1	-13.2
Total Energy Generated and Received	2,122.0	2,084.9
Sales to Ultimate Consumers	1,634.2	1,620.1
Sales for Resale	349.3	321.2
Transmission Losses	131.9	137.9
Other	6.6	5.7
Total Sales and Disposition	2,122.0	2,084.9
Revenues From Sales of Electricity (billions of dollars)		
Residential	32.5	28.5
Commercial	26.5	22.4
Industrial	27.1	23.1
Others	2.7	2.4
Total Revenues from Sales to Ultimate Consumers	88.9	76.4
Resales	11.9	9.7
Total Revenues from Sales of Electric Energy	100.8	86.1
Other Revenues	1.5	1.0
Total Electric Operating Revenues	102.3	87.1
Number of Customers (in millions, average per month)		
Residential	63.4	62.3
Commercial and Industrial	7.8	7.6
Other	0.7	0.7
Total Customers	71.9	70.6

[a] Aggregate capacity data for 1981 are provisional and subject to revision.

Source: Federal Energy Regulatory Commission Form 1 and predecessor systems.

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ACID RAIN:

CONTROL STRATEGIES FOR COAL-FIRED UTILITY BOILERS

VOLUME I

MAY 1982

UNITED STATES DEPARTMENT OF ENERGY
MORGANTOWN ENERGY TECHNOLOGY CENTER
MORGANTOWN, WEST VIRGINIA

ACID RAIN:

CONTROL STRATEGIES FOR COAL-FIRED UTILITY BOILERS

VOLUME I

By

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Contract No. DE-AC21-81MC16361

May 1982

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ACKNOWLEDGMENT

This report was prepared for the U.S. Department of Energy, Morgantown Energy Technology Center, under the direction of Mr. Timothy W. Devitt. Mr. Michael F. Szabo was the project manager, and Mr. Yatendra M. Shah was the control technology assessment task manager. Other persons providing assistance in preparing this report included Messrs. John Abraham, Gary Baker, N. David Noe, Douglas Orf, Radha Krishnan, Thomas Ponder, and Edward Zawadski, consultant.

The authors appreciate the cooperation and guidance provided by the project officer, Mr. Richard Harrington.

EXECUTIVE SUMMARY

INTRODUCTION

This report presents a detailed evaluation of the cost and effectiveness of conventional controls for emissions of sulfur oxides (SO_x) and nitrogen oxides (NO_x) from coal-fired utility boilers. The cost and control efficiency data are based on analyses of the 50 U.S. utility plants emitting these pollutants in the greatest quantities in 1979 (the 50 highest emitters for each pollutant, with some overlap of plants emitting large amounts of both). These plant-specific data can be used to verify other cost-effectiveness models, such as those from ICF and Teknekron, that were developed on a generic basis. The methodology and results of this evaluation have been used for review of assumptions and cost estimates prepared by the U.S. EPA for participation in the National Acid Rain Assessment Plan (NARAP) and the U.S Canadian Transboundary Group.

The study is based on the premise that coal-fired utility power plants in the midwestern United States are the major contributors to the acid rain problem in the Northeast. This premise and other important factors in the acid rain problem are addressed in a companion report assessing the overall acid rain issue. The assessment concludes that reducing SO_x and NO_x

emissions from midwestern coal-fired power plants may not significantly reduce the acidity of rain, even at the cost of billions of dollars for controls. In fact, local sources of SO_x and NO_x, chiefly oil-fired boilers and automobiles in the Northeast, may contribute more significantly to the acid rain occurring there than previously realized. In view of the current uncertainty about the relative importance of various possible contributors to the acid rain problem, the utility evaluation reported here, which is detailed and plant-specific, should prove valuable in further investigations.

UNCONTROLLED EMISSIONS AND SO_x/NO_x CONTROL STRATEGIES

Uncontrolled SO_x emissions from the 50 highest utility emitters in 1979 totalled about 8.6 million tons. Total U.S. SO_x emissions from all sources were estimated at 30.2 million tons in 1977, the latest year for which emissions data are available. Uncontrolled NO_x emissions from the 50 highest utility emitters in 1979 were an estimated 2.4 million tons. The total U.S. NO_x emissions from all sources were estimated at 25.5 million tons in 1977. If the nationwide emissions remained relatively constant through 1979, then the 50 highest SO_x emitters contributed about 30 percent of the total SO_x emissions, and the 50 highest NO_x emitters contributed nearly 10 percent of the total NO_x emissions.

The control strategies evaluated in this report are limited to conventional or currently available techniques. The SO_x

control options considered herein are: firing low-sulfur coal, physical coal cleaning, wet flue gas desulfurization (FGD) with limestone (at 90 percent and 60 percent removal efficiencies) and dry FGD with lime. Two NO_x control techniques are considered: overfire air and low-NO_x burners. The emission reduction gained by applying each control technique was calculated for each plant, but not all of the techniques are applicable to each plant. Table 1 summarizes the potential emission reduction achievable through "blanket" implementation of the different control strategies at all 50 plants (where applicable). Figure 1 shows the impact of these potential reductions on (1) total U.S. SO_x emissions, (2) total utility SO_x emissions, and (3) total SO_x emissions from the 50 highest utility emitters. This figure demonstrates that the impact of controlling the 50 highest SO_x emitters is by far the greatest within that group alone, and lessens considerably with respect to total U.S. and total utility emissions.

COST SUMMARY

In addition to potential emission reduction data, Table 1 and Figure 2 also show the costs and cost effectiveness of applying the control strategies at all 50 plants. It is readily apparent that limestone FGD designed for 90 percent removal is the most costly SO_x control strategy and also is the most effective. Firing of low-sulfur eastern coal appears to be the most cost-effective SO_x control strategy.

TABLE 1. SUMMARY OF EMISSION REDUCTIONS AND CONTROL COSTS
(1980 dollars)

Control strategy	Annual emission, reduction, %	Annual emission, reduction, 10^3 tons	Capital costs $\$ \times 10^6$	Capital costs Cost-effectiveness, \$/ton	Annualized costs $\$ \times 10^6$	Annualized costs Cost-effectiveness, \$/ton
SO_x						
Low-sulfur eastern coal	68.7	5,934	2,319	391	1,255	211
Low-sulfur western coal	64.1	5,533	2,992	541	3,825	691
Physical coal cleaning	17.4	1,503	1,270	845	869	578
Limestone FGD (90%)	90.0	7,769	11,037	1,421	3,595	463
Limestone FGD (60%)	60.0	5,179	6,871	1,327	2,245	433
Dry FGD[a]	3.7	323	668	2,068	237	734
NO_x						
Overfire air and low-NO_x burners	19.8	483	298	617	46	95

[a] Applicable at only three of the 50 power plants.

The generation of cost data for a control strategy is not to be construed as a recommendation of that strategy for controlling emissions. The cost data shown are intended to form an input to the models optimizing the control strategies for a population of plants. The optimization models can be structured to account for various interrelated factors for the plant population and then select emission control strategy for each individual plant.

For example, potential supply-demand constraints due to future major emission reduction requirements for utility power plants must be considered in selecting the control strategies for individual power plants. Similarly, socio-economic problems, such as job losses related to use of low-sulfur coals, or capability of transportation systems to handle additional quantities of low-sulfur western coals must be evaluated. Only the consideration of such extraneous factors in conjunction with the generated cost data, can provide an optimized emission control plan for the plant population being analyzed.

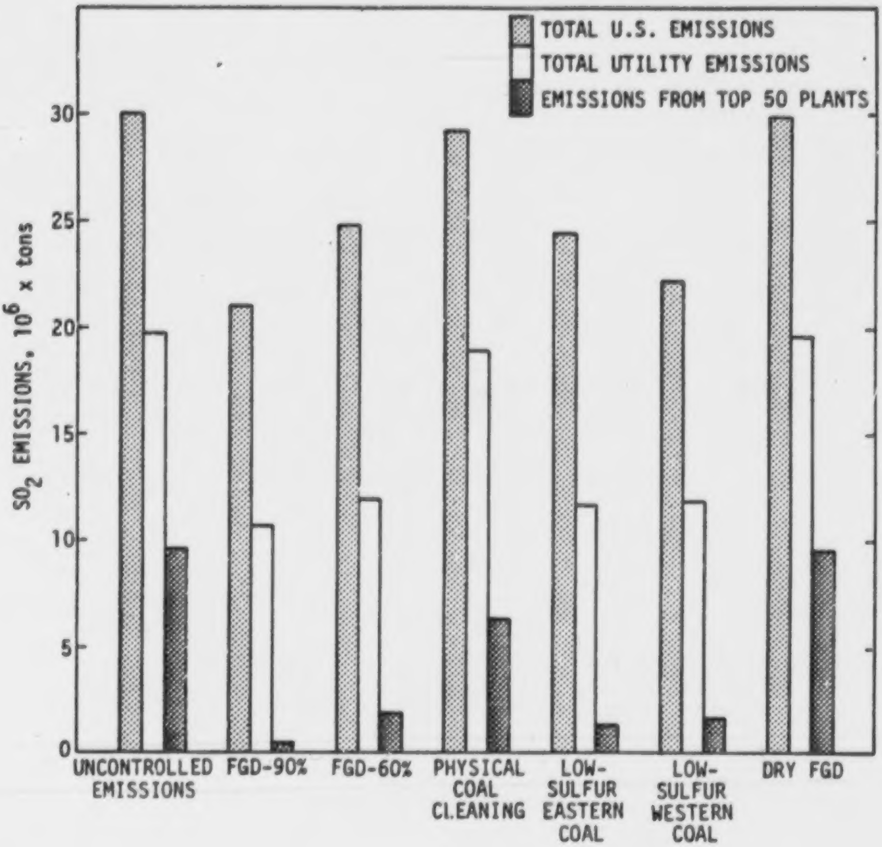

Figure 1. Impact of controlling SO_x emissions from top 50 utility emitters.

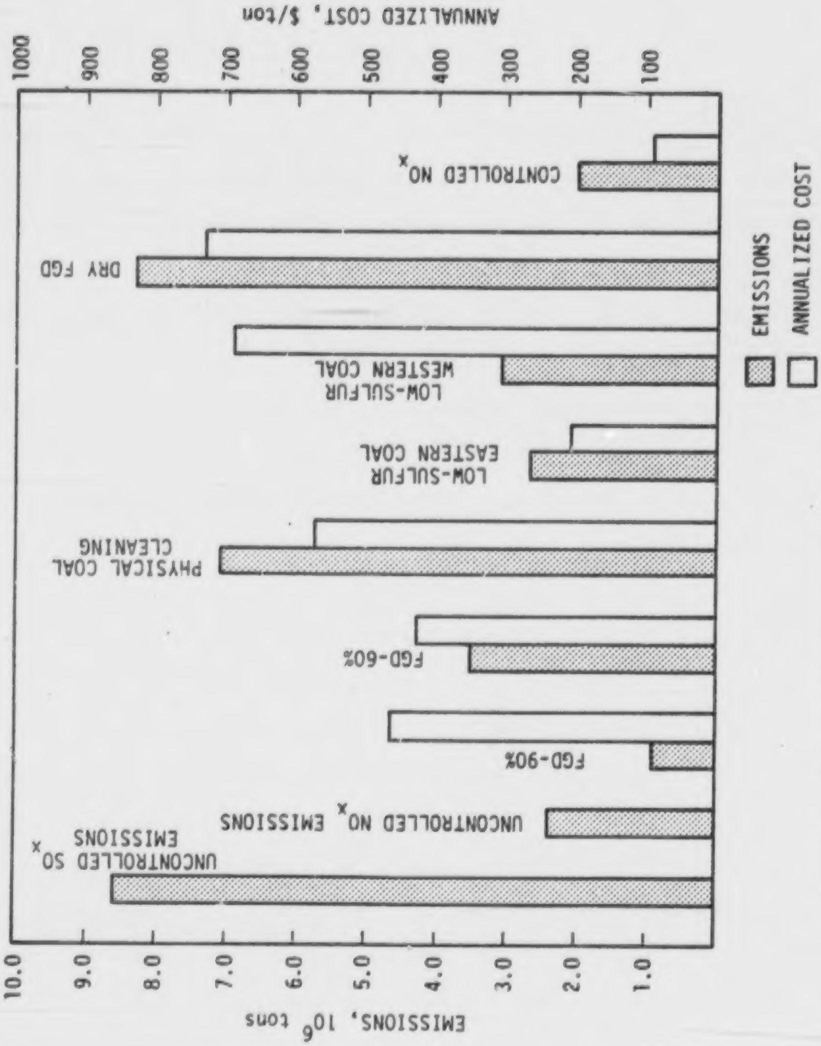

Figure 2. Uncontrolled/controlled emissions and cost effectiveness of SO_x and NO_x control strategies.

SECTION 1

INTRODUCTION

As part of the efforts of the U.S. Department of Energy (DOE) to study the issues related to the causes and effects of acidic precipitation, the Morgantown Energy Technology Center (METC) of the DOE has been assigned lead responsibility within DOE's Office of Fossil Energy for evaluation of acid rain control strategies.

There are three main areas of investigation: (1) evaluation of control methods that would minimize emissions contributing to acid rain formation, including estimates of costs and effectiveness of the methods; (2) investigation of the acid rain issue, including historical perspective, scientific bases of the phenomena, and critical effects on ecological systems and other factors (e.g., visibility) (3) technical guidance for direction of the METC programs dealing with emerging technologies for solutions to the acid rain problem. This report addresses Item 1. A companion report[1] concerns the impact of local sources, and a third report addresses controversial acid rain issues as well as a commentary on the role of oil burning.

This report is based upon the premise that large coal-fired utility power plants in the Midwest generate most of the sulfur and nitrogen oxides emissions contributing to the acid rain problem in the northeastern United States (often called the "long-range transport" theory). It identifies the efficiency factors and costs associated with several control strategies to minimize these emissions from the 50 utility plants that generate them in greatest quantities. If the premise is valid, control of these major sources of precurser pollutants should reduce the acid rain problem in the Northeast; if the premise is faulty, then such controls probably would not alleviate the problem. It should be noted that the two companion reports[1,2] to this one, as well as other investigations, indicate that oil-fired sources and automobiles in and near the affected areas of the Northeast may contribute more to acid rain occurrence than previously realized. In any event, this plant-by-plant assessment of major utility emissions, potential controls, and costs provides firm data that will aid in the evaluations that are prerequisite to implementation of controls.

Section 2 of this report describes the procedures used to determine the utility sources responsible for the largest quantities of SO_x and NO_x emissions. The cost methodology is also discussed. Section 3 presents the evaluation of four SO_x control strategies for each of the utility sources identified in Section 2. Four control strategies were investigated: (1) switching to low-sulfur coals, (2) firing physically cleaned coal, (3) installing wet flue gas desulfurization (FGD) systems, and (4) installing dry flue gas desulfurization systems. The applicability, emission control efficiency, and costs of each strategy are discussed. Section 4 gives an evaluation of NO_x control strategies for the 50 major utility sources, presenting emission factors, state-of-the-art control technologies, and control system costs and efficiencies.

REFERENCES FOR SECTION 1

1. Spaite, et al. Acid Rain: The Impact of Local Sources. PEDCo Environmental and Paul W. Spaite Co. Prepared for U.S. Department of Energy, Morgantown Energy Technology Center. Contrat No. DE-AR-21 80MC14787. November 1980.

2. PEDCo Environmental and Paul W. Spaite Co. Acid Rain: A Critical Assessment of Controversial Issues. Prepared for U.S. Department of Energy. Morgantown Energy Technology Center. Draft May 1981.

3. Szabo, M., P. Spaite and P. Esposito. Commentary on Controversial Issues and Observations on the Role of Fuel Burning, PEDCo Environmental and Paul W. Spaite Company. Prepared to U.S. Department of Energy, Research Triangle Park under Contract No. DE-A (21-8) MC16361.

SECTION 2

STUDY APPROACH, DATA BASE, AND COST METHODOLOGY

2.1 APPROACH AND DATA BASE

The National Coal Association (NCA) annually publishes data on fuel quality and consumption for all utility power plants of capacity greater than 25 MW. The first step in this evaluation study was to examine the 1978 NCA data[1] for each individual coal- and oil-fired utility power plant in 31 states (excluding the "western" states whose emissions are not considered suspect in the northeast U.S. acid rain issue) and the District of Columbia (Table 2-1). Uncontrolled SO_x emissions were calculated for each facility from U.S. EPA emission factors (AP-42).[2]

Emissions of NO_x depend upon the quantity of fuel consumed and the type of boiler. A coal-fired cyclone boiler, for example, emits 3 times more NO_x than a typical pulverized-coal-fired boiler. The 1978 NCA data indicated the largest coal-consuming plants, and a list of utility cyclone boilers was compiled.

Uncontrolled emissions of SO_x and NO_x in 1979 were computed for about 120 large power plants from information reported on Form 67 of the Federal Power Commission (FPC).* The FPC forms

---

* Steam-Electric Plant Air and Water Quality Control Data for the Year Ended December 31, 1979.[6]

TABLE 2-1. STATES WHOSE INDIVIDUAL UTILITY SO_x EMISSIONS WERE COMPUTED

Alabama	Minnesota
Arkansas	Mississippi
Connecticut	Missouri
Delaware	New Hampshire
District of Columbia	New Jersey
Florida	New York
Georgia	North Carolina
Illinois	Ohio
Indiana	Pennsylvania
Iowa	Rhode Island
Kentucky	South Carolina
Louisiana	Tennessee
Maine	Vermont
Maryland	Virginia
Massachusetts	West Virginia
Michigan	Wisconsin

give detailed boiler and fuel information, and some plants were contacted directly. From these computations, the 50 plants generating the greatest quantities of uncontrolled SO_x and NO_x emissions in 1979 were determined; these plants are listed, with emissions data, in Tables 2-2 and 2-3. Figures 2-1 and 2-2 show the plant locations.

In 1977, an estimated 30.2 million tons of SO_x and 25.5 million tons of NO_x were emitted nationwide.[3] Stationary fuel combustion by electric utilities accounted for 64.2 percent of the SO_x and 30.7 percent of the NO_x. The 50 largest uncontrolled SO_x emitters (Table 2-2) emitted 9.04 million tons of SO_x in 1979, almost 30 percent of the amount discharged in 1977 from all sources and 47 percent of total U.S. utility plant emissions. The Conesville, Mansfield, and Petersburg plants use FGD systems to clean some or all of their flue gas. Discounting the total for the SO_x removal at these three plants, the 50 major emitters discharged approximately 8.6 million tons of SO_x. The 50 major NO_x emitters (Table 2-3) emitted an estimated 2.4 million tons of NO_x in 1979, nearly 10 percent of the total amount discharged in 1977 from all sources and 31 percent of total utility plant emissions. Thus, reducing SO_x and NO_x emissions at these facilities could significantly reduce the nationwide total; moreover, if it is determined that power plants in the Midwest contribute strongly to the acid rain problem, control of emissions at these 50 plants could ameliorate that problem also.

TABLE 2-2. FIFTY HIGHEST UNCONTROLLED SO_x EMITTERS IN 1979
(Asterisk indicates plants also among the 50 largest NO_x emitters)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	SO_x	NO_x
1. Paradise*	Tennessee Valley Authority	KY	4967.4	10,600	4.2	396.40	136.60
2. Gavin*	Ohio Electric Co.	OH	8217.9	9,260	2.4	374.74	73.96
3. Muskingum River*	Ohio Power Co.	OH	3828.5	10,430	5.1	370.98	62.24
4. Monroe*	Detroit Edison	MI	6483	12,412	2.56	315.33	58.35
5. Cumberland*	Tennessee Valley Authority	TN	4867.4	10,820	3.4	314.33	43.81
6. Clifty Creek*	Indiana-Kentucky Electric Corp.	IN	3928.9	10,968	4.01	299.34	58.93
7. Baldwin*	Illinois Power Co.	IL	5160.3	10,547	3.0	294.14	141.91
8. Conesville*	Columbus & Southern Ohio Electric	OH	3633.1	10,808	4.25	293.37	42.01
9. Gibson*	Public Service Co. of Indiana	IN	5296	10,700	2.8	281.75	47.66
10. Labadie*	Union Electric Co.	MO	5547.4	10,781	2.42	255.07	49.93
11. Kyger Creek*	Ohio Valley Electric Corp.	OH	3098	11,242	3.84	226.03	46.47
12. Mitchell*	Ohio Power Co.	WV	3384.6	11,767	3.33	214.14	30.46
13. Bowen*	Georgia Power Co.	GA	5994.67	11,728	1.84	209.57	53.95
14. Mansfield*	Pennsylvania Power Co.	PA	3445	11,375	3.07	200.95	31.01
15. Sammis*	Ohio Edison Co.	OH	3967.8	11,604	2.5	188.47	35.71

(continued)

TABLE 2-2 (continued)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	SO_x	NO_x
16. Hatfield*	West Penn Power Co.	PA	3820.8	11,875	2.5	181.49	34.39
17. Petersburg	Indianapolis Power and Light Co.	IN	2948.1	10,953	3.16	177.00	26.53
18. New Madrid*	Associated Electric Coop.	MO	2932.57	10,584	3.17	176.63	80.65
19. Homer City*	Pennsylvania Electric Co.	PA	4757	11,667	1.95	176.25	42.81
20. Cardinal*	Ohio Power Co.	OH	4608.5	11,543	2.0	175.12	41.48
21. Johnsonville	Tennessee Valley Authority	TN	2954.9	11,220	3.1	174.04	26.59
22. Gaston*	Alabama Power Co.	AL	4821.5	11,823	1.83	167.64	43.39
23. Wansley*	Georgia Power Co.	GA	4553	11,111	1.9	164.36	40.98
24. Eastlake	Cleveland Electric Illuminating Co.	OH	2445.5	12,169	3.47	161.23	22.01
25. Harrison	Monongahela Power Co.	WV	3223.4	12,666	2.6	159.24	29.01
26. Coffeen*	Central Illinois Public Service Co.	IL	2261.8	9,263	3.7	159.00	62.20
27. Brunner Island*	Pennsylvania Power and Light Co.	PA	3796	12,497	2.2	158.67	34.16
28. Kammer*	Ohio Power Co.	WV	1841	11,792	4.34	151.81	50.63
29. Kincaid*	Commonwealth Edison Co.	IL	2248	10,147	3.53	150.77	61.82
30. Warrick	Alcoa Generating Corp.	IN	2291.6	11,045	3.31	144.12	20.62

(continued)

TABLE 2-2 (continued)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	SO_x	NO_x
31. Keystone*	Pennsylvania Electric Co.	PA	4169.9	11,836	1.77	140.23	37.53
32. Stuart*	Dayton Power and Light Co.	OH	5936	11,173	1.2	135.34	53.42
33. Cayuga	Public Service Co. of Indiana	IN	2846	10,289	2.5	135.19	25.61
34. Montour*	Pennsylvania Power and Light Co.	PA	3941.1	12,507	1.7	127.30	35.47
35. Shawnee	Tennessee Valley Authority	KY	3168.8	11,860	2.1	126.44	28.52
36. Gallatin	Tennessee Valley Authority	TN	2748.3	11,890	2.6	122.43	22.30
37. Thomas Hill*	Associated Electric Coop.	MO	1408.55	9,760	4.48	119.96	24.12
38. Conemaugh	Pennsylvania Electric Co.	PA	2680	12,136	2.35	119.66	24.12
39. Amos*	Appalachian Power Co.	WV	7618.2	11,840	0.81	117.24	68.56
40. Avon Lake	Cleveland Electric Illuminating Co.	OH	2219.6	11,953	2.75	116.48	20.29
41. Beckjord	Cincinnati Gas and Electric Co.	OH	2457.4	10,753	2.49	116.26	22.12
42. Joppa	Electric Energy, Inc.	IL	2911.004	11,577	2.09	115.60	26.20
43. Cobb	Consumers Power Co.	MI	1555.9	11,199	3.87	114.56	19.92

(continued)

TABLE 2-2 (continued)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	SO_x	NO_x
44. Miami Fort	Cincinnati Gas and Electric Co.	OH	2747.2	11,371	2.08	108.95	24.97
45. Ft. Martin	Monongahela Power Co.	WV	2967.9	12,113	1.9	107.14	26.71
46. Kingston*	Tennessee Valley Authority	TN	3985	11,550	1.4	106.00	35.87
47. Colbert	Tennessee Valley Authority	AL	2447.9	11,500	2.2	102.32	22.03
48. Oak Creek	Wisconsin Electric Power Co.	WI	2543	11,443	2.1	101.47	22.89
49. Big Bend*	Tampa Electric Co.	FL	2381.7	11,475	2.2	99.56	35.73
50. Sioux*	Union Electric Co.	MO	2343.4	10,206	2.22	98.84	64.44

TABLE 2-3. FIFTY HIGHEST UNCONTROLLED NO_x EMITTERS IN 1979
(Asterisk indicates plant also among 50 largest SO_x emitters)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	NO_x	SO_x
1. Baldwin*	Illinois Power Co.	IL	5160.3	10,547	3.0	141.91	294.14
2. Paradise*	Tennessee Valley Authority	KY	4967.4	10,600	4.2	136.60	396.40
3. Powerton	Commonwealth Edison Co.	IL	3242	9,763	1.31	89.16	80.69
4. New Madrid*	Associated Electric Coop.	MO	2932.57	10,584	3.17	80.65	176.63
5. Gavin*	Ohio Electric Co.	OH	8217.9	9,260	2.4	73.96	374.74
6. Amos*	Appalachian Power Co.	WV	7618.2	11,840	0.81	68.56	117.24
7. Sioux*	Union Electric Co.	MO	2343.4	10,206	2.2	64.44	98.84
8. Muskingum River*	Ohio Power Co.	OH	3828.5	10,430	5.1	62.24	370.98
9. Coffeen*	Central Illinois Public Service Co.	IL	2261.8	9,263	3.7	62.20	159.00
10. Kincaid*	Commonwealth Edison Co.	IL	2248	10,147	3.53	61.82	150.77
11. Clifty Creek*	Indiana-Kentucky Electric Corp.	IN	3928.9	10,968	4.01	58.93	299.34
12. Monroe*	Detroit Edison Co.	MI	6483	12,412	2.56	58.35	315.33
13. Bowen*	Georgia Power Co.	GA	5994.67	11,728	1.84	53.95	209.57
14. Stuart*	Dayton Power and Light Co.	OH	5936	11,173	1.2	53.42	135.34
15. Kammer*	Ohio Power Co.	WV	1841	11,792	4.34	50.63	151.81

(continued)

TABLE 2-3 (continued)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	NO_x	SO_x
16. Labadie*	Union Electric Co.	MO	5547.4	10,781	2.42	49.93	255.07
17. Gibson*	Public Service Co. of Indiana	IN	5296	10,700	2.8	47.66	281.75
18. Kyger Creek*	Ohio Valley Electric Corp.	OH	3098	11,242	3.84	46.47	226.03
19. Cumberland*	Tennessee Valley Authority	TN	4867.4	10,820	3.4	43.81	314.33
20. Gaston*	Alabama Power Co.	AL	4821.5	11,823	1.83	43.39	167.64
21. Allen	Tennessee Valley Authority	TN	1570.8	11,690	2.3	43.20	68.64
22. Homer City*	Pennsylvania Electric Co.	PA	4757	11,667	1.95	42.81	176.25
23. Gannon	Tampa Electric Co.	FL	2348.3	12,174	1.3	42.80	68.90
24. Conesville*	Columbus and Southern Ohio Electric	OH	3633.1	10,808	4.25	42.01	293.37
25. Belews Creek	Duke Power Co.	NC	4629.98	12,028	0.89	41.67	78.29
26. Cardinal*	Ohio Power Co.	OH	4608.5	11,543	2.0	41.48	175.12
27. Wansley*	Georgia Power Co.	GA	4553	11,111	1.9	40.98	164.36
28. Michigan City	Northern Indiana Public Service Co.	IN	1453.26	10,493	2.53	39.96	69.86
29. Sherburne	Northern States Power Co.	MN	4403.86	8,615	0.74	39.63	61.92
30. Thomas Hill*	Associated Electric Coop.	MO	1408.55	9,760	4.48	38.73	119.96

(continued)

TABLE 2-3 (continued)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	NO_x	SO_x
31. Marshall	Duke Power Co.	NC	4173.68	12,082	1.02	37.56	80.89
32. Keystone*	Pennsylvania Electric Co.	PA	4169.9	11,836	1.77	37.53	140.23
33. Joliet	Commonwealth Edison Co.	IL	3413	9,423	0.61	37.50	39.51
34. Neal	Iowa Public Service Co.	IA	3398.3	9,542	0.74	36.19	47.78
35. Kingston*	Tennessee Valley Authority	TN	3985	11,550	1.4	35.87	106.00
36. Big Bend*	Tampa Electric Co.	FL	2381.7	11,475	2.2	35.73	99.56
37. Sammis*	Ohio Edison Co.	OH	3967.8	11,604	2.5	35.71	188.47
38. Montour*	Pennsylania Power and Light Co.	PA	3941.1	12,507	1.7	35.47	127.30
39. King	Northern States Power Co.	MN	1269.79	9,004	1.3	34.92	31.36
40. St. Clair	Detroit Edison Co.	MI	3439	9,747	0.66	34.41	47.21
41. Hatfield*	West Penn Power Co.	PA	3820.8	11,875	2.5	34.39	181.49
42. Brunner Island*	Pennsylvania Power and Light Co.	PA	3796	12,497	2.2	34.16	158.67
43. Will County	Commonwealth Edison Co.	IL	2577	9,208	0.5	33.97	24.48
44. Columbia	Wisconsin Power and Light Co.	WI	3766.44	8,516	0.52	33.90	37.21
45. Roxboro	Carolina Power and Light Co.	NC	3720	12,282	0.71	33.48	50.18

(continued)

TABLE 2-3 (continued)

Plant	Utility	State	Coal consumption	Coal properties		Emissions, 10^3 tons	
			10^3 tons	Btu/lb	%S	NO_x	SO_x
46. Widows Creek	Tennessee Valley Authority	AL	3549.5	11,920	0.8	31.95	53.95
47. Mansfield*	Pennsylvania Power Co.	PA	3445	11,375	3.07	31.01	200.95
48. Mitchell*	Ohio Power Co.	WV	3384.6	11,767	3.33	30.46	214.14
49. Bailly	Northern Indiana Public Service Co.	IN	1089.37	10,721	2.88	29.96	59.61
50. Karn	Consumers Power Co.	MI	1383.4	11,231	2.35	29.17	79.49

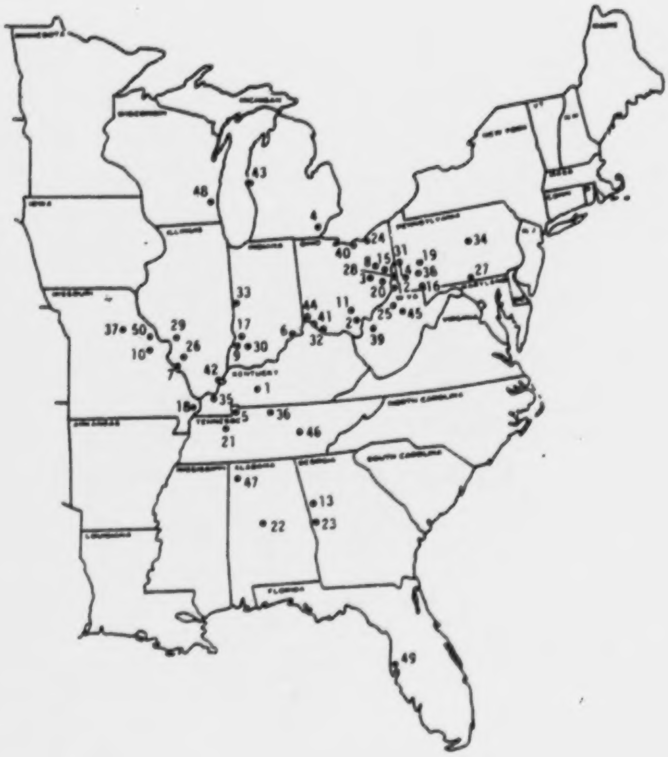
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Figure 2-1. Locations of the 50 largest uncontrolled SO_x emitters - 1979.

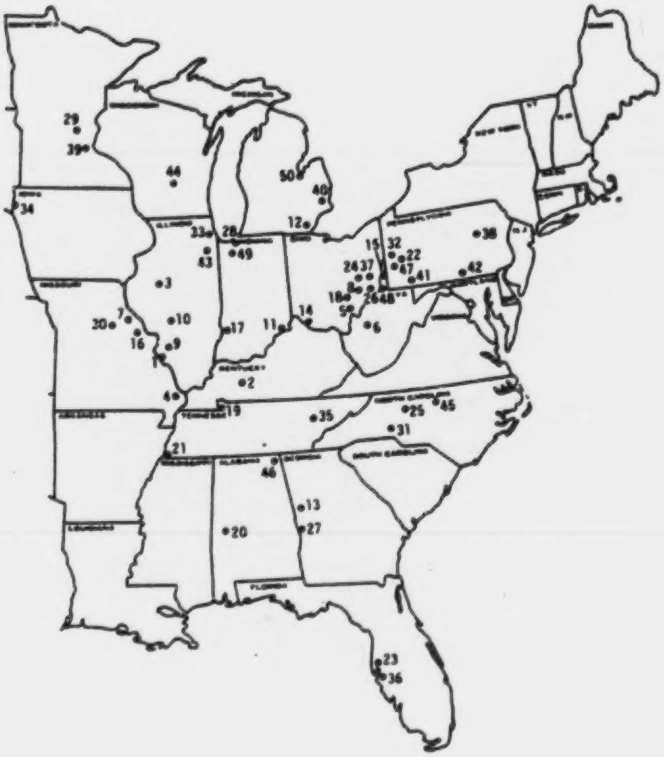
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Figure 2-2. Locations of the 50 largest uncontrolled NO_x emitters - 1979.

2.2 COST METHODOLOGY

The methods of estimating costs for each SO_x and NO_x control strategy depend on a specified scope of application for each strategy. PEDCo's wet FGD computer cost program was revised to reflect 1980 costs and current process and system trends. Dry FGD system costs were obtained from 1980 vendor quotes but were applied only to three plants because the effectiveness of dry FGD in high-sulfur coal applications has not been demonstrated. Costs for the low-sulfur eastern and western coals were prepared on a state-by-state basis. Three standard cleaning plant configurations were defined to encompass the coal washability characteristics of fuels fired at the 50 plants. Cost models were developed to predict the costs for the three configurations, with plant capacity as the input variable. The scope of this investigation did not include such factors as the effects of converting large numbers of power plants to low-sulfur coal or blanket application of FGD systems. These factors are treated in detail in other models.

All of the control strategy cost estimates are in 1980 dollars. The annual operating, maintenance, and fixed costs were treated as uniformly as possible so as to provide a common basis for comparison of the strategies.

Capital and annualized costs were estimated for each control strategy as applied to each plant. The capital cost represents the initial investment necessary to install and commission the system. The annualized cost represents the cost of operating and maintaining the system and the fixed charges for recovery of the capital investment.

Capital costs consist of direct and indirect costs incurred before the commissioning of the facility. Direct costs include the costs of various equipment items and the labor and materials required for installing these items and interconnecting the system. Indirect costs are expenditures for the overall facility that cannot be attributed to specific equipment; they include such items as freight and spares.

The "bought-out" cost of the equipment and the cost of installing it are considered direct costs. A bought-out cost is the purchase price paid on a freight-on-board (f.o.b.) basis, not including freight charges. Installation costs cover the interconnection of piping and electrical equipment and the other work needed to commission the system, as well as the costs of foundations, supporting structures, enclosures, ducting, control panels, instrumentation, insulation, painting, and similar items. Installation costs also include site development, construction of access roads and walkways, and establishment of any required rail, barge, or truck facilities. The cost of administrative facilities is also a direct cost.

Indirect costs include the following:

Interest: interest accrued on borrowed capital during construction.

Engineering costs: administrative, process, project, and general costs; design and related functions for specifications; bid analysis; special studies; cost analysis; accounting; reports; purchasing; procurement; travel expenses; living expenses; expediting; inspection; safety; communications; modeling; pilot plant studies; royalty payments during construction; training of plant personnel; field engineering; safety engineering; and consultant services.

Field overhead: cost of securing permits and right-of-way sections, and the cost of insurance for the equipment and personnel on site.

Freight: delivery costs of process and related equipment shipped f.o.b. point of origin.

Offsite expenditures: costs of powerhouse modifications, interruption to power generation, and service facilities added to the existing plant facilities.

Taxes: sales, franchise, property, and excise taxes.

Spare parts: costs of items stocked to permit 100 percent process availability; such items include pumps, valves, controls, special piping and fittings, instruments, spray nozzles, and similar equipment.

Shakedown: costs associated with system startup.

Contractor's fee and expenses: costs for field labor payroll, supervision, field office, administrative personnel, construction offices, temporary roadways, railroad trackage, maintenance and welding shops, parking lot, communications, temporary piping, electrical, sanitary facilities, rental equipment, unloading and storage of materials, travel expenses, permits, licenses, taxes, insurance, overhead, legal liabilities, field testing of equipment, and labor relations.

Contingency costs: costs resulting from malfunctions, equipment design alterations, and similar unforeseen sources.

Land cost: costs for the wet FGD strategy include only the cost of the land required for sludge disposal. The cost of land for installing FGD equipment is accounted for in the installation factors.

All indirect costs except land cost are obtained by multiplying the direct costs by an indirect cost factor. The land cost is based on land rate and the disposal area requirement for each facility.

The annualized operating costs consist of the following:

Raw materials: for example, costs of lime or limestone for the FGD system and fixation chemicals.

Utilities: costs of water for slurries, cooling, and cleaning; electricity for pumps, fans, valves, lighting controls, conveyors, and mixers; fuel for reheating flue gases; and steam for processing.

Operating labor: costs of supervision and skilled and unskilled labor to operate, monitor, and control the process.

Maintenance and repairs: costs of manpower and materials used in preventive and corrective maintenance to keep the unit operating efficiently.

Overhead: business expenses that are not charged directly to a particular part of a process, but are allocated to it. These include administrative, safety, engineering, legal, and medical services; payroll; employee benefits; recreation; and public relations.

The capital investment is generally translated into annual fixed charges. These charges, along with the annual operating cost, represent the total annualized cost of a system. The annual fixed charges are calculated under three cost components: depreciation, insurance, and capital charges, whose values are obtained as follows:

Depreciation: calculated by using a sinking-fund method over the life period of the system.

Insurance: calculated by multiplying the total capital cost by the insurance rate.

Capital charges: calculated by multiplying the total capital cost by the input interest rate. Capital charges represent the interest paid annually for use of capital and vary with interest rates.

The total annual fixed charge is the sum of values of the four components. The annualized cost is the sum of the annual operating costs and the total annual fixed charge.

To estimate the annual operating costs, one must estimate both the quantities of raw materials, utilities, and labor, and also the unit price of each of these items, such as dollars per man-hour for labor. Table 2-4 shows unit prices for the annual operating costs of the different control strategies. Figures 2-3 and 2-4 show the 1979 estimated delivered costs of low-sulfur eastern and low-sulfur western coals, respectively.

TABLE 2-4. UNIT PRICES USED IN CONTROL STRATEGY COST ESTIMATES

State	Lime, \$/ton	Electricity, mills/kWh	Reheat, \$/10^6 Btu
Alabama	46.34	26.72	1.34
Florida	59.35	36.47	1.82
Georgia	44.87	32.53	1.63
Illinois	38.22	31.54	1.58
Indiana	38.22	27.95	1.40
Kentucky	43.34	20.76	1.04
Michigan	44.68	36.35	1.82
Missouri	42.69	26.85	1.34
Ohio	45.46	25.43	1.27
Pennsylvania	48.84	33.70	1.68
Tennessee	43.34	21.69	1.08
West Virginia	43.34	22.79	1.14
Wisconsin	48.41	32.53	1.63

Constant values:

Direct labor - \$12.20/man-hour
Fixation chemicals - \$20.00/ton
Limestone - \$12.00/ton
Sludge handling - \$0.50/ton-mile
Water - \$0.22/10^3 gal

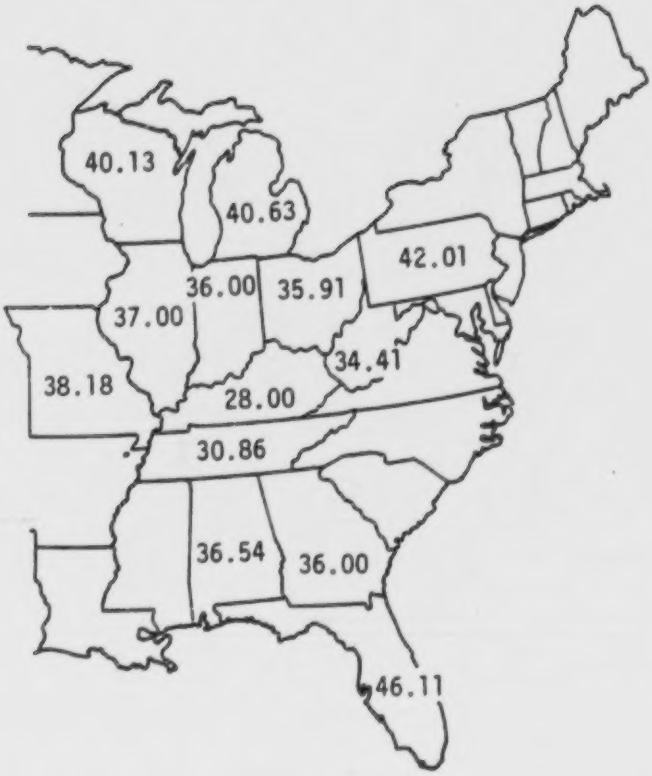
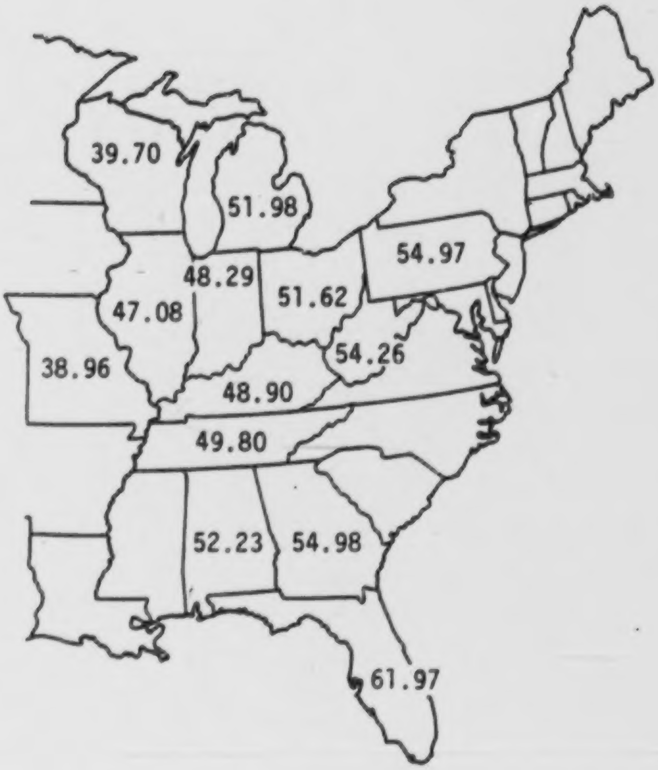

40.13
40.63
42.01
36.00
35.91
37.00
34.41
38.18
28.00
30.86
36.54
36.00
46.11

Figure 2-3. Estimated delivered costs of low-sulfur eastern coal, $/ton. (Base year 1979)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51.98
54.97
48.29
51.62
47.08
54.26
38.96
48.90
49.80
52.23
54.98
61.97

Figure 2-4. Estimated delivered costs of low-sulfur western coal, \$/ton. (Base year 1979)

REFERENCES FOR SECTION 2

1. National Coal Association. Steam Electric Plant Factors 1979.

2. U.S. EPA. Compilation of Air Pollutant Emission Factors. AP-42, Part A. August 1977.

3. U.S. EPA. National Air Quality, Monitoring, and Emissions Trends Report, 1977. EPA-450/2-78-052, December 1978. p. 5-12.

SECTION 3

SO_x CONTROL STRATEGIES

This report evaluates four currently available SO_x control technologies and their applicability at the 50 utility power plants identified in Section 2. The methods considered are (1) the use of low-sulfur coal, (2) physical coal cleaning, (3) wet FGD, and (4) dry FGD.

The first two control methods are designed to reduce the sulfur content of the fuel fired at a given plant, one simply by the purchase and use of coal with an inherently lower sulfur content than the coal fired currently and the other by physical cleaning of coal to remove sulfur and other impurities. Wet and dry FGD systems combine chemical and physical processes to remove the SO_x from the flue gases leaving a boiler.

3.1 USE OF LOW-SULFUR COAL

In evaluation of conversion to low-sulfur fuel, two typical coals were selected: a low-sulfur western (LSW) and a low-sulfur eastern coal (LSE),

Coal	Sulfur content, %	Ash content, %	Heating value, Btu/lb
LSE	0.9	9.0	12,700
LSW	1.0	10.0	12,200

In a change from one source of coal to another, the physical and chemical properties of the coals can affect furnace/ boiler operation. Full-scale combustion testing is the most reliable method of evaluating coal from a new source. This investigation assumes that boiler operating characteristics would not be greatly affected by a change to low-sulfur coal and that plant modifications would be minimal.

The plant modifications most likely to be needed would involve the coal preparation equipment and the electrostatic precipitators (ESP's). In general, western coals are harder and thus are more difficult to pulverize than the eastern coals now fired at the 50 plants. In estimates of the costs associated with increasing the pulverizer capacity for the LSW coal option, it is assumed that space limitations would not preclude such modifications. No change in pulverizer capacity would be needed at plants with cyclone boilers. For the LSE coal option, it is assumed that the grindability of LSE coal is comparable to that of coals currently fired and that the present pulverizer capacity is adequate.

The effect of a fuel change on ESP performances depends largely on the ash resistivity, the flue gas flow rate, and the allowable emission rate. The ash resistivity of low-sulfur coals is greater than that of medium or high-sulfur coals. Where boiler flue gas rates are to be maintained at about current levels when LSE or LSW coals are fired, the capacity of the ESP's must be increased to hold emission rates at or below the current levels.

Capital cost estimates for plant modifications (boiler and ESP) at each plant include the direct equipment costs as well as indirect costs and contingency. Tables 3-1 and 3-2 summarize the cost estimates for LSE and LSW options, respectively. Detailed breakdowns of the cost components for each plant are given in Appendix A.

For estimates of the annual operating and maintenance (O&M) costs associated with boiler and ESP modifications, the capital investment was translated into annual capital charges, which include the following components: general and administrative costs, taxes, insurance, and a capital-recovery factor (a levelized principal and interest payment). These charges, along with the annual O&M costs, constitute the annualized cost of plant modifications.

Utility plants report fuel costs to the DOE on FPC Form 423, "Monthly Report of Cost and Quality of Fuels for Electric Plants." A DOE summary of these utility reports[1] shows the average cost of coal delivered to each of the 50 plants. It also gives cost and quality data on deliveries from coal-producing districts to each state. With this information, the cost of a low-sulfur coal comparable in quality to the LSE coal as defined for this study was estimated on a state-by-state basis for all of the 50 plants. Based on each plant's 1979 coal consumption and the heating value, the required tonnage of LSE coal was computed for each plant, yielding a fuel cost differential for firing LSE coal at each plant. Firing the LSE coal

TABLE 3-1. ESTIMATED COSTS OF FIRING LOW-SULFUR EASTERN COAL AT THE 50 HIGH-EMISSIONS PLANTS

Plant	SO_x reduction, %	Capital costs		Annualized costs			
		Plant modifications,		Plant modifications, $ x 10^6/yr	Fuel differential, $ x 10^6/yr	Total,	
		$ x 10^6	$/kW			$ x 10^6/yr	mills/kWh
1. Paradise	82.1	54.60	21.35	10.88	32.00	42.88	3.71
2. Gavin	72.7	72.60	27.92	14.56	(35.00)[a]	(20.44)	(1.26)
3. Muskingum River	85.5	43.24	28.27	9.16	22.40	31.56	3.50
4. Monroe	65.6	96.02	29.28	20.00	39.90	59.90	3.33
5. Cumberland	77.4	73.72	28.35	14.15	(16.80)	(2.65)	(0.24)
6. Clifty Creek	80.6	40.54	31.10	9.61	39.20	48.81	5.68
7. Baldwin	75.1	56.59	29.91	11.66	41.30	52.96	4.55
8. Conesville[b]	82.0	45.68	38.35	9.04	11.60	20.64	5.44
9. Gibson	72.9	68.05	25.47	13.49	36.60	50.09	4.12
10. Labadie	68.4	72.30	32.57	14.65	70.30	84.95	7.44
11. Kyger Creek	79.3	33.99	31.29	7.92	25.00	32.92	4.53
12. Mitchell	75.0	52.16	31.95	10.48	4.90	15.38	1.60
13. Bowen	54.0	82.29	26.04	17.06	10.20	27.26	1.71
14. Mansfield[c]							
15. Sammis	67.1	64.31	27.92	13.10	10.60	23.70	2.38
16. Hatfield	66.3	44.85	25.96	9.60	57.20	66.80	6.83

(continued)

TABLE 3-1 (continued)

Plant	SO_x reduction, %	Capital costs		Annualized costs			
		Plant modifications,		Plant modifications, $ x 10^6/yr	Fuel differential, $ x 10^6/yr	Total,	
		$ x 10^6	$/kW			$ x 10^6/yr	mills/kWh
17. Petersburg[d]	75.4	19.05	26.30	3.93	19.80	23.73	6.59
18. New Madrid	76.3	26.50	22.09	5.31	29.50	34.81	5.60
19. Homer City	57.6	47.20	25.51	10.12	43.40	53.52	4.12
20. Cardinal	59.1	55.04	29.27	11.05	22.60	33.65	2.89
21. Johnsonville	74.4	70.98	47.79	16.28	(8.80)	7.48	1.13
22. Gaston	54.2	74.37	36.95	15.32	1.80	17.12	1.37
23. Wansley	58.6	45.52	26.31	9.40	13.70	23.10	2.10
24. Eastlake	75.1	43.87	34.90	9.12	(5.00)	4.12	0.70
25. Harrison	65.5	66.53	32.42	13.35	11.90	25.25	2.89
26. Coffeen	82.3	25.60	25.46	5.22	16.50	21.72	5.12
27. Brunner Island	59.7	45.33	29.09	9.71	31.70	41.41	4.03
28. Kammer	80.7	24.39	34.23	5.45	25.70	31.15	6.49
29. Kincaid	79.6	31.18	23.62	6.16	10.30	16.46	3.51
30. Warrick	76.4	27.22	37.19	5.75	20.50	26.25	5.82
31. Keystone	52.6	42.32	22.61	8.86	53.40	62.26	5.73
32. Stuart	34.0	58.11	23.81	11.73	8.90	20.63	1.50
33. Cayuga	70.8	28.14	26.50	5.78	29.80	35.58	5.84
34. Montour	47.9	38.78	25.28	8.18	34.80	42.98	4.08

(continued)

TABLE 3-1 (continued)

Plant	SO_x reduction, %	Capital costs		Annualized costs			
		Plant modifications, $ x 10^6	Plant modifications, $/kW	Plant modifications, $ x 10^6/yr	Fuel differential, $ x 10^6/yr	Total,[a] $ x 10^6/yr	Total,[a] mills/kWh
35. Shawnee	60.0	52.18	29.81	12.23	(33.80)	(21.57)	(2.80)
36. Gallatin	67.6	63.53	50.61	13.31	(20.30)	(6.49)	(0.98)
37. Thomas Hill	84.6	15.91	33.15	3.32	14.60	17.92	6.52
38. Conemaugh	63.4	47.33	25.28	9.46	13.50	22.96	3.24
39. Amos[e]							
40. Avon Lake	69.3	39.23	36.15	8.22	0.30	8.52	1.65
41. Beckjord	69.4	41.05	35.32	8.60	10.10	18.70	3.13
42. Joppa	60.7	38.72	35.65	9.55	7.40	16.95	2.37
43. Cobb	79.5	28.64	56.10	7.12	6.00	13.12	3.72
44. Miami Fort	61.4	47.04	36.69	9.49	8.90	18.39	2.92
45. Fort Martin	54.8	29.53	25.68	6.10	8.20	14.30	2.01
46. Kingston	41.5	58.76	34.10	13.82	(14.00)	(0.18)	(0.02)
47. Colbert	63.0	46.72	32.92	9.96	(2.60)	7.36	1.27
48. Oak Creek	61.4	67.03	40.13	14.51	18.80	33.31	4.66
49. Big Bend	63.0	40.00	29.99	8.34	25.50	33.84	5.45
50. Sioux	67.4	32.42	29.48	6.51	15.80	22.31	4.40

[a] Parentheses indicate a negative value, i.e., cost savings.

[b] Low-sulfur coal option evaluated for Boilers 1 through 4 only. Boilers 5 and 6 use FGD.

[c] Low-sulfur coal option not evaluated because plant uses FGD.

[d] Low-sulfur coal option evaluated for Boilers 1 and 2 only. Boiler 3 uses FGD.

[e] Low-sulfur coal option not evaluated for the Amos plant because sulfur content of coal currently fired is lower than that of the proposed LSE coal.

TABLE 3-2. ESTIMATED COSTS OF FIRING LOW-SULFUR WESTERN COAL AT THE 50 HIGH-EMISSION PLANTS

Plant	SO_x reduction, %	Capital costs		Annualized costs			
		Plant modifications,		Plant modifications, $ x 10^6/yr	Fuel differential, $ x 10^6/yr	Total,	
		$ x 10^6	$/kW			$ x 10^6/yr	mills/kWh
1. Paradise	79.3	55.18	21.57	11.05	127.00	138.05	11.94
2. Gavin	68.4	78.52	30.20	15.77	71.80	87.57	5.41
3. Muskingum River	83.2	42.25	27.62	9.03	78.40	87.43	9.71
4. Monroe	60.3	151.06	46.06	29.20	125.30	154.50	8.58
5. Cumberland	73.9	84.93	32.67	16.07	70.20	86.27	7.91
6. Clifty Creek	77.6	52.18	40.03	12.05	87.60	99.65	11.60
7. Baldwin	71.2	62.23	32.89	12.81	92.70	105.51	9.07
8. Conesville[a]	79.2	51.32	43.09	10.04	39.90	49.94	13.15
9. Gibson	68.7	78.64	29.43	15.39	100.30	115.69	9.52
10. Labadie	63.5	85.43	38.48	17.01	81.50	98.51	8.63
11. Kyger Creek	76.0	40.15	36.96	9.12	73.90	83.02	11.43
12. Mitchell	71.0	72.47	44.40	13.84	74.10	87.94	9.18
13. Bowen	47.8	120.13	38.02	23.45	127.70	151.15	9.48
14. Mansfield[b]							
15. Sammis	62.0	88.22	38.30	17.03	75.20	92.23	9.27
16. Hatfield	61.1	67.51	39.07	13.47	111.50	124.97	12.78

(continued)

TABLE 3-2 (continued)

Plant	SO_x reduction, %	Capital costs		Annualized costs			
		Plant modifications,		Plant modifications, $ x 10^6/yr	Fuel differential, $ x 10^6/yr	Total	
		$ x 10^6	$/kW			$ x 10^6/yr	mills/kWh
17. Petersburg[c]	71.6	23.62	32.61	4.73	42.20	46.93	13.04
18. New Madrid	72.6	27.13	22.61	5.48	35.30	40.78	6.56
19. Homer City	51.0	69.17	37.39	13.96	109.80	123.76	9.52
20. Cardinal	52.7	70.29	37.38	13.61	97.20	110.81	9.51
21. Johnsonville	70.3	84.44	56.86	18.89	46.00	64.89	9.84
22. Gaston	47.0	100.12	49.76	19.72	81.80	101.52	8.12
23. Wansley	52.1	58.20	33.64	11.66	98.30	109.96	10.01
24. Eastlake	71.3	62.53	49.75	12.24	36.70	48.94	8.36
25. Harrison	60.1	107.10	52.19	19.85	82.90	102.75	11.76
26. Coffeen	79.5	27.32	27.17	5.59	36.40	41.99	9.89
27. Brunner Island	53.4	71.35	45.79	14.19	88.60	102.79	10.00
28. Kammer	77.7	28.71	40.29	6.33	63.40	69.73	14.53
29. Kincaid	76.4	32.86	24.89	6.50	31.90	38.40	8.18
30. Warrick	72.6	33.18	45.33	6.82	48.90	55.72	12.36
31. Keystone	45.2	65.53	35.00	12.84	112.50	125.34	11.53
32. Stuart	23.7	73.31	30.03	14.29	102.00	116.29	8.45
33. Cayuga	66.3	31.11	29.30	6.38	62.70	69.08	11.34
34. Montour	39.7	64.49	42.04	12.51	93.90	106.41	10.11

(continued)

TABLE 3-2 (continued)

Plant	SO_x reduction, %	Capital costs		Annualized costs			
		Plant modifications,		Plant modifications, $ x 10^6/yr	Fuel differential, $ x 10^6/yr	Total	
		$ x 10^6	$/kW			$ x 10^6/yr	mills/kWh
35. Shawnee	53.7	71.71	40.98	15.88	34.00	49.88	6.48
36. Gallatin	62.5	81.92	65.28	17.16	28.40	45.56	6.88
37. Thomas Hill	82.2	16.57	34.53	3.47	17.20	20.67	7.52
38. Conemaugh	57.7	73.92	39.49	13.75	52.50	66.25	9.35
39. Amos[d]							
40. Avon Lake	64.5	54.27	50.02	10.77	37.50	48.27	9.37
41. Beckjord	64.6	44.37	38.18	9.20	47.20	56.40	9.44
42. Joppa	54.6	54.35	50.04	12.76	39.30	52.06	7.29
43. Cobb	76.3	32.74	64.13	8.01	24.50	32.51	9.21
44. Miami Fort	55.3	59.61	46.50	11.59	52.80	64.39	10.22
45. Fort Martin	47.7	32.26	40.11	8.85	70.70	79.55	11.18
46. Kingston	32.4	75.92	44.06	17.19	62.10	79.29	8.08
47. Colbert	57.2	59.88	42.20	12.29	36.90	49.19	8.47
48. Oak Creek	55.3	85.22	51.03	17.80	21.50	39.30	5.49
49. Big Bend	57.2	56.92	42.59	11.23	65.10	76.33	12.30
50. Sioux	62.3	32.25	32.06	7.08	20.20	27.28	5.37

[a] Low-sulfur coal option has been evaluated for Boilers 1 through 4 only. Boilers 5 and 6 use FGD.

[b] Low-sulfur coal option not evaluated because plant uses FGD.

[c] Low-sulfur coal option evaluated for Boilers 1 and 2 only. Boiler 3 uses FGD.

[d] Low-sulfur coal option not evaluated for the Amos plant because sulfur content of coal currently fired is lower than that of the proposed LSW coal.

results in a fuel cost savings at the Gavin and Eastlake plants in Ohio and at TVA's Cumberland, Johnsonville, Shawnee, Gallatin, Kingston, and Colbert plants. The statewide breakdown of LSE coal costs may have influenced the apparent effects on individual plant costs. Moreover, coal costs are extremely variable, depending greatly on such factors as coal quality, transportation, coal purchasing practices, and market fluctuations.

Analysis of the actual 1979 coal costs at each of the plants that exhibited cost savings through the LSE coal option shows a wide range of coal costs for coals of different sulfur contents (Table 3-3). This variation indicates that parameters other than sulfur content must affect coal prices. Some of these parameters were identified.

Coal costs at the Eastlake plant in northeast Ohio probably are affected by the cost of transport from sources elsewhere in Ohio and from West Virginia and Kentucky. Costs at the Gavin plant in southeast Ohio apparently are affected by market factors, i.e., a commitment to purchase coal from company-owned mines at a cost above the general market price. The average cost of coal at Gavin was 164 cents per million Btu in 1979, whereas the average for all 50 plants was 123 cents per million Btu.

The factors affecting TVA plants showing a conversion cost savings are similar for each plant and are therefore discussed collectively. One relates to suits against TVA for failing to

TABLE 3-3. VARIATION OF 1979 COAL COSTS BY SULFUR CONTENT RANGES ($¢/10^6$ Btu)

Plant	State	Sulfur content <1.0%		Sulfur content 1.0-2.0%		Sulfur content ≥2.0%		Average cost
		Low	High	Low	High	Low	High	
Gavin	Ohio	122.1	203.7	126.5	144.7	88.7	232.4	164.36
Cumberland	Tennessee			105.5	105.5	94.3	170.6	137.43
Johnsonville	Tennessee	179.1	200.9	97.1	145.6	77.0	162.0	134.76
Eastlake	Ohio	155.1	185.2	92.5	216.4	104.9	190.6	149.85
Shawnee	Kentucky	114.3	212.3	127.7	153.7	76.7	185.5	155.23
Gallatin	Tennessee	152.5	179.3	140.0	187.1	81.5	193.4	155.89
Kingston	Tennessee	97.5	154.2	83.6	182.2	77.4	181.0	136.67
Colbert	Alabama			83.5	182.6	93.2	160.0	148.52

comply with environmental regulations. Settlement of the suits under consent decrees included interim standards for SO_x control at 10 TVA plants including the six cited above. Under long-term contracts for low-sulfur coal supplies, the average cost for the six plants was 22 cents per million Btu above the average paid by the total 50 plants. The other factor contributing to the negative fuel differential at the six TVA plants is transportation. All but one are located some distance from the low-sulfur coal sources and the difficulty of transporting LSE coals to these sites probably is not accounted for in the statewide LSE coal cost estimates.

Based on the LSW coal characteristics described earlier, costs were obtained for similar coal purchased under long-term contract from a Western supplier at the mine. The cost of transporting the coal by unit train to the states of interest was added to the cost of the coal. The required tonnage and the resulting fuel cost differential were then estimated in the same manner as for the LSE coal option.

The evaluations of the LSE and LSW coal options are based on several assumptions, one of which is that the coal supply will be adequate. Although this investigation has identified supplies of coals similar in quality to the LSE and LSW coals postulated for evaluation, the extent of minable reserves of such fuels may be limited. Similarly, the cost of the low-sulfur coal could be affected if some 50 utilities were to initiate a sudden increase in the demand for low-sulfur coal, possibly inflating the price above that assumed in the evaluation. Finally, although it is assumed that adequate means are available for transporting the coal to each plant, a sudden increase in demand on the railroad industry might not be met instantly. This would be particularly important to the LSW evaluation; transportation capabilities in the west are not as well developed as in the east, and the need to transport LSW coal to the east by several haulers could increase the transportation costs.

The fuel differential cost, along with the annualized plant modifications cost, represents the total annualized cost of implementing the low-sulfur coal options. Tables 3-1 and 3-2 summarize the estimated costs associated with implementing the LSE and LSW coal options at the 50 high-emission plants. Appendix A gives detailed breakdowns of the individual cost components for each plant and the estimated costs of LSE and LSW coals by state.

The plants listed on Tables 3-1 and 3-2 emitted an estimated 8,632.32 x 10^3 tons of SO_x in 1979. The analysis just described indicates that SO_x emissions could be reduced by approximately 68.7 percent or 64.1 percent through the LSE or LSW coal options, respectively. Table 3-4 summarizes the degree of control and the costs of implementing the low-sulfur coal control strategies.

TABLE 3-4. SUMMARY OF SO_x EMISSIONS REDUCTION AND COSTS AT THE 50 LARGEST SO_x EMITTERS

Control option	SO_x reduction, %	Controlled SO_x emissions, 10^3 tons	Capital cost, \$ x 10^6	Annual cost, \$ x 10^6/yr
LSE	68.7	2,698.09	2,319.24	1,255.42
LWS	64.1	3,099.36	2,992.59	3,825.45

3.2 PHYSICAL COAL CLEANING

Most of the 50 highest SO^2 emitters currently fire coals that can be physically cleaned to reduce the sulfur content. The amount of possible SO^2 reduction by physical coal cleaning depends upon the washability characteristics of the coal and the degree of cleaning. This type of cleaning can remove only the pyritic sulfur, which is contained in inorganic material. Potential benefits are greatest where maximum reductions in ash and pyritic sulfur contents can be attained without excessive loss of coal in the process refuse. Depending on the washing characteristics of the coal, physical coal cleaning can reduce SO^2 emissions by as much as 40 percent, with an associated coal loss of about 10 to 15 percent. Typical SO^2 reductions would be in the range of 20 to 30 percent. Intensive cleaning yields relatively larger SO^2 reductions, but also causes loss of coal heating value and requires an expensive cleaning plant.

The physical and chemical compositions of coal are not homogeneous; substantial variability can occur from seam to seam and even within a single seam. A coal cleaning plant designed for one mine may not provide a similar clean product for a coal from another mine. In the planning of a coal preparation plant, enough coal samples must be analyzed to provide good washability data. These data are the basis for selection of coal cleaning equipment.

The costs of coal cleaning plants for the 50 major SO_2 emitters are estimated in this section, as well as the potential reductions in SO_2 emissions.

Analytical Approach

A generic cost estimating approach, as outlined below, was used to determine the costs of coal cleaning options for the 50 major SO_2 emitters.

1. Collection of FPC forms for current (1979) data on the coal quality, quantity, and supply for each plant.
2. Identification of the coal seam supplying each plant and, where possible, the current cleaning practices, if any.
3. Evaluation of the cleaning potential of each seam by comparison of the reported coal quality with coal washability data for the seam, as reported by the United States Bureau of Mines (USBM).
4. Development of three basic coal preparation plant configurations.
5. Selection of a cleaning plant configuration for each power plant, as indicated by seam washability characteristics and degree of cleaning attainable.

6. Development of process data, such as cleaning plant capacity, sulfur recovery, and Btu recovery for each plant.

7. Development of order-of-magnitude cost estimates.

The three plant configurations used in this study are: (1) dense-medium cyclone plant, (2) a jig and demister table plant, and (3) a heavy-medium vessel and demister table plant.

The FPC data identify the coal supplier by mine, county, and state. Identification of the coal seam for each plant was possible only where published data on the coal mine are available. The principle source of data was the Keystone Coal Buyers Manual.

Washing characteristics of coal from the seam were obtained primarily from USBM data, which represent the theoretical sulfur removal potential of a large number of U.S. coals. The data are based on washability tests of channel and run-of-mine (ROM) samples crushed to top sizes of 1-1/2 in., 3/8 in., and 14 mesh; these data identify the potential for enhancing sulfur removal by crushing the coal to liberate pyritic sulfur.

The principal constraints on the USBM data are:

1. The data are often based on a channel sample, whereas the utility plants use ROM coal. Channel samples are usually taken from the seam by hand as a vertical section, which includes all coal and partings from the mine roof to the point of flow. Run-of-mine coal contains all coal plus mineral dilution (rock, shale) associated with the mine roof and floor.

2. The extent to which the samples tested by the USBM represent the seam characteristics is not known; however, the data are assumed to be indicative of the general washing characteristics of the coal seams.

Compilation of Coal Delivery Data

Selection of the type and size of coal cleaning plant for each power plant was based on 1979 coal delivery data reported by each utility on FPC Form 423. The data consist of fuel quantity, analysis, origin, and price for each fuel supply source.

A summary of 1979 coal delivery data was prepared for each plant. Table 3-5 shows a sample summary for the Cumberland plant. Each summary lists the mines that supplied coal to the plant. The total delivered coal quantity from each supplier was obtained by adding the quantities for individual months. Since the coal analysis and price of the coal vary from month to month, the summary gives ranges of these values for the year.

Selection of Cleanable Coals and Quantities

Each of the 50 plants obtained coal from more than one source in 1979, and one plant had as many as 100 suppliers. The 1979 coal supply data were used to identify coal seams, and the cleaning potential was evaluated from the reported coal quality and published washability data for the coal seam. Cleaning potential of the coals at a Btu recovery rate of at least 90 percent were estimated from the published data. In cases where the FPC data did not indicate coal seams, the most expensive of

TABLE 3-5. SUMMARY OF COAL DELIVERY DATA, CUMBERLAND PLANT

Source		% of total plant Btu	Ranges of coal properties			
Mine	County/state		Btu	Sulfur, %	Ash, %	Cost, ¢/10^6 Btu
Hamilton	Union, Ky.	22.8	11,775-11,899	2.6-2.7	7.8-8.6	151.7-170.1
River Queen	Muhlenberg, Ky.	9.4	10,934-11,416	3.0-3.2	11.1-13.2	95.5-153.0
Camp Mines	Union, Ky.	54.1	10,368-10,586	3.8-3.9	17.8-18.6	101.8-181.5
Crooks	Spencer, Ind.	0.0	11,000	2.7	13.5	120.0
Valley	Hocking, Ohio	0.1	11,000	2.9	14.8	103.4-104.3
Circle S No. 3	Ohio, Ky.	0.0	11,200	2.9	13.1	101.2
BB & M	Gallia, Ohio	0.0	11,500	2.3	13.8	109.4
Hatfield	Ohio, Ky.	0.1	11,200	2.9	13.1	99.2-111.6
Robb Pit	Pike, Ind.	0.0	11,000	2.9	13.1	94.3
Indicoal	Hancock, Ky.	0.3	11,000	2.8	13.1	106.4
Big Valley	Carter, Ky.	0.1	11,500	1.8	13.7	105.5
Pyro Mines	Union, Ky.	2.1	12,286-12,411	2.9-3.0	9.5-10.1	97.3-158.4
Coonville	Hocking, Ohio	0.0	11,000	2.9	14.8	110.6
Bright Star No. 10	Perry, Ind.	0.1	11,100	2.7	13.1	106.8
Stephens Pit	Pike, Ind.	0.1	11,000	2.7	13.1	113.6
Jackson	Butler, Ky.	0.3	11,500	2.3	12.5	111.7

the three types of coal cleaning evaluated (plant No. 1) was assumed to estimate cleaning costs.

Coal Cleaning Devices

The three cleaning plant configurations used in this analysis are representative of domestic cleaning plants. Jigs, heavy-media vessels, demister tables, and cyclones are the principal cleaning devices, with the following distribution:

	% of total
Heavy media	25.0
Heavy media/tables	28.6
Tables	3.4
Jigs	20.7
Jigs/tables	2.3
Other combinations of jigs/tables/heavy media	20.0
	100.0

- In a jig device a bath of pulsating water flows through a bed of material, and the "jigging" action causes the heavy material to settle to the bottom while the lighter material rises to the top. Jigs operate most effectively on coal sized at 3 in. x 1/4 in. Separation efficiency can be high when little near-gravity material is present, and typical applications show good separations at high gravities, usually above 1.50.
- A concentrating table consists of a ribbed rubber-mounted deck and a drive mechanism. Movement of the deck causes the coal/water slurry to flow across the "table;" the lighter-gravity material is carried to

the lower side of the table (shortest distance between feed and discharge), and the heavier material is moved to the far side of the table. Concentrating tables can clean coals in the 3/4 in. x 0 size range, but are used mainly for 1/2 in. x 28 mesh coals. Separations occur at gravities above 1.45, and are sharpest when little near-gravity material is present.

- Heavy-media vessels operate most efficiently with coals larger than 1/4 in. These devices consist of tanks equipped with mechanisms (chains, baffles) that remove float material from a moving bath of magnetite (or other heavy media) and water. Clean coal floats and is collected at the top. Heavy-media vessels provide sharper separation than jigs or tables.
- Heavy-media cyclones have been used successfully to clean fine coal, down to 100 mesh, at all practical gravities. They separate clean coal from mineral matter by both gravity and centrifugal forces. A slurry of coal, magnetite, and water is fed tangentially to the cyclone. Clean coal is removed in the overflow and refuse in the underflow.

Model Cleaning Plants

The three coal cleaning plant configurations were defined so as to accommodate the characteristics of coals used by the 50 high-emission plants. The plant configurations are described in the following paragraphs.

1. Heavy-Media Cyclone Plant

The raw coal is crushed to 1-1/2 in. size in a two-stage crushing circuit. The crushed product is screened into size fractions of 3/8 in. x 0 and 1-1/2 in. x 3/8 in., which are sent to separate cleaning circuits. The 3/8 in. x 0 stream is further screened to separate a 3/8 in. x 28 mesh fraction and a 28 mesh x 0 fraction. The 28 mesh x 0 coal is sent to a plant clarifier for dewatering and then disposed of as refuse.

The 1-1/2 in. x 3/8 in. and 3/8 in. x 28 mesh coals are cleaned in two separate heavy-media cyclone circuits. These circuits consist of similar cleaning equipment. The refuse streams from the two cleaning circuits are disposed of along with the dewatered 28 mesh x 0 coal. The clean coal from the two heavy-media cyclone circuits is dewatered in centrifuges, the recovered water is returned to the circuits, and clean coal is transferred to clean coal piles. The heavy-media cyclone circuits also include magnetite circulation and recovery circuits. Figure 3-1 shows a schematic of a heavy-media cyclone coal cleaning plant.

2. Jig and Concentrating Table Plant

The crushing equipment for this plant is similar to that in a heavy-media cyclone plant. Coal from the crushing circuit is screened into two fractions: 1-1/2 in. x 3/8 in. and 3/8 in. x 0. The 3/8 in. x 0 coal is further screened to separate a 28 mesh x 0 fraction, which is dewatered and disposed of as refuse.

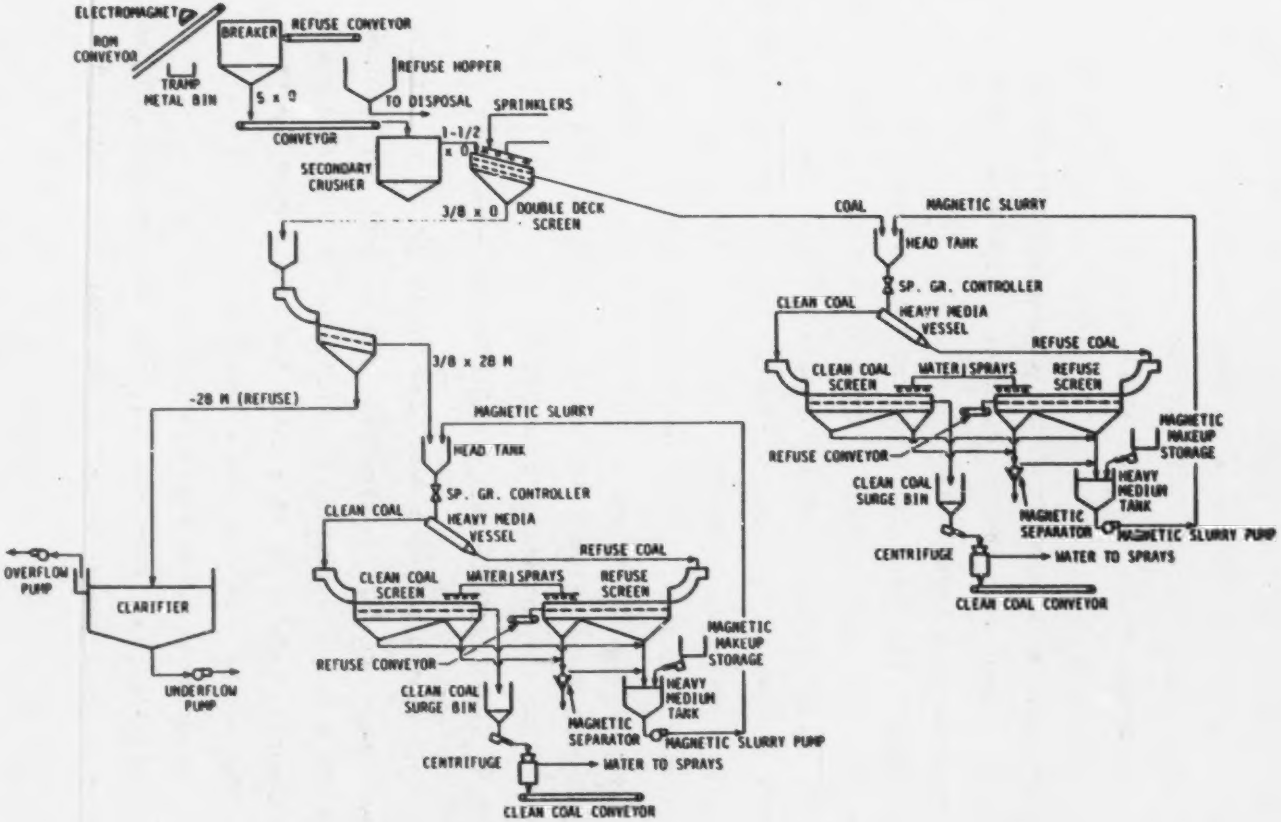
ELECTROMAGNET
ROM CONVEYOR
TRAMP METAL BIN
BREAKER
REFUSE CONVEYOR
5 x 0
REFUSE HOPPER
TO DISPOSAL
CONVEYOR
SECONDARY CRUSHER
1-1/2 x 0
SPRINKLERS
3/8 x 0
DOUBLE DECK SCREEN
COAL
MAGNETIC SLURRY
HEAD TANK
SP. GR. CONTROLLER
CLEAN COAL
HEAVY MEDIA VESSEL
REFUSE COAL
CLEAN COAL SCREEN
WATER SPRAYS
REFUSE SCREEN
MAGNETIC MAKEUP STORAGE
REFUSE CONVEYOR
CLEAN COAL SURGE BIN
HEAVY MEDIUM TANK
MAGNETIC SEPARATOR
MAGNETIC SLURRY PUMP
CENTRIFUGE
WATER TO SPRAYS
CLEAN COAL CONVEYOR
3/8 x 28 M
-28 M (REFUSE)
OVERFLOW PUMP
CLARIFIER
UNDERFLOW PUMP

Figure 3-1. Heavy-media cyclone coal cleaning plant.

The coarse coal (1-1/2 in. x 3/8 in.) is cleaned in a jig cleaning circuit. The 3/8 in. x 28 mesh coal is cleaned in a concentrating table circuit. The clean coals from the two circuits are dewatered in separate centrifuges and sent to plant storage. The refuse coal from the jig circuit is sent to disposal. The refuse stream from the concentrating tables is dewatered in a centrifuge before disposal. Figure 3-2 shows a jig and concentrating table plant.

3. Heavy-Media Vessel and Concentrating Table Plant

The crushing and screening circuit for this plant is similar to those of the other two plants. The coarse coal is cleaned in a heavy-media vessel circuit. For the 3/8 in. x 28 mesh coal, concentrating tables are used. The heavy-media vessel circuit is similar to the heavy media cyclone circuit in plant 1, except that heavy-media vessels are used in place of heavy-media cyclones. Figure 3-3 shows a schematic of a heavy-media vessel and concentrating table plant.

Selection of Cleaning Plant Configurations for Industrial Utility Plants

The following discussion describes selection of a cleaning plant configuration for the Eastlake power plant. A similar approach was used in selecting the configuration likely to yield optimum cleaning capability at each of the 50 major SO_2-emitting plants. The method thus combines a model approach with a plant-by-plant selection based on site-specific data.

Eastlake Plant - Two mines supplied 67.1 percent of the coal fired at this plant in 1979. The coal was identified as

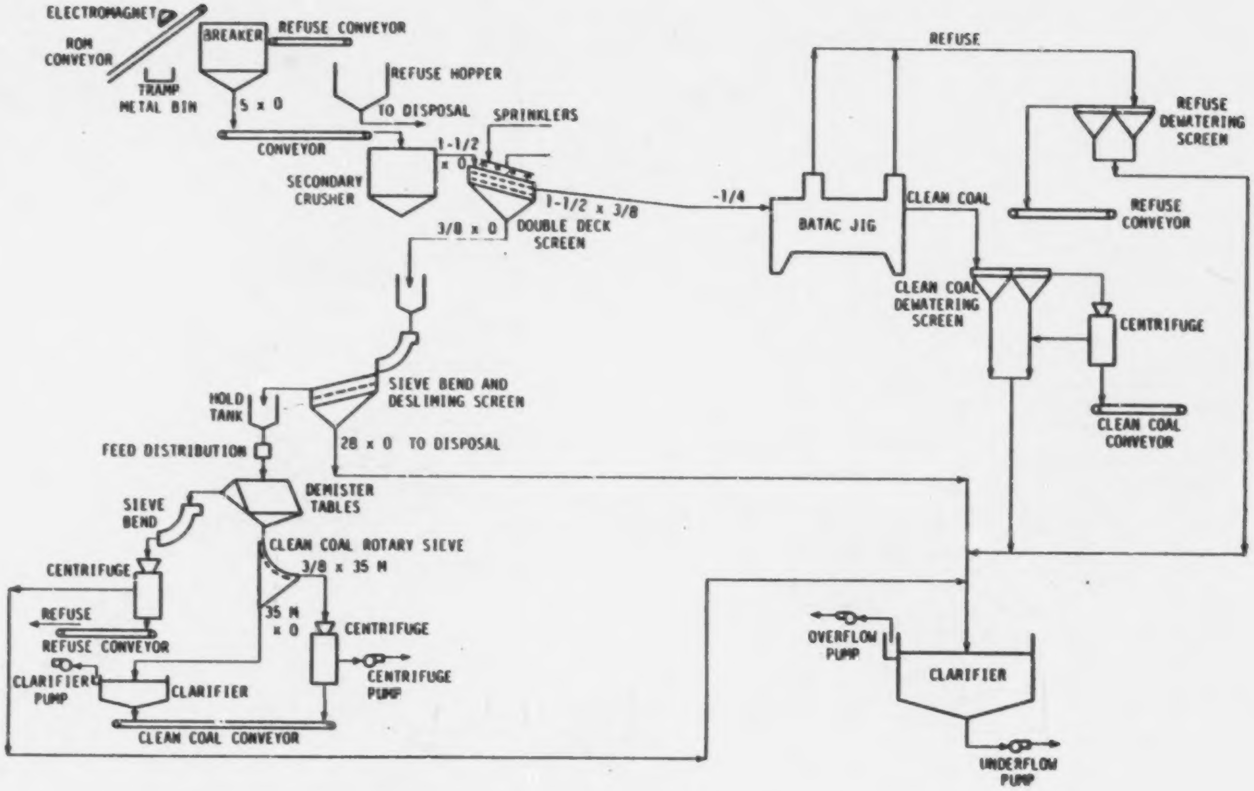
ELECTROMAGNET
ROM CONVEYOR
TRAMP METAL BIN
BREAKER
REFUSE CONVEYOR
5 x 0
REFUSE HOPPER
TO DISPOSAL
CONVEYOR
SECONDARY CRUSHER
1-1/2 x 0
SPRINKLERS
DOUBLE DECK SCREEN
1-1/2 x 3/8
3/8 x 0
-1/4
BATAC JIG
REFUSE
CLEAN COAL
REFUSE DEWATERING SCREEN
REFUSE CONVEYOR
CLEAN COAL DEWATERING SCREEN
CENTRIFUGE
CLEAN COAL CONVEYOR
SIEVE BEND AND DESLIMING SCREEN
HOLD TANK
28 x 0 TO DISPOSAL
FEED DISTRIBUTION
DEMISTER TABLES
SIEVE BEND
CLEAN COAL ROTARY SIEVE
3/8 x 35 M
35 M x 0
CENTRIFUGE
REFUSE
REFUSE CONVEYOR
CENTRIFUGE
CENTRIFUGE PUMP
CLARIFIER PUMP
CLARIFIER
CLEAN COAL CONVEYOR
OVERFLOW PUMP
CLARIFIER
UNDERFLOW PUMP

Figure 3-2. Jig and concentrating table coal cleaning plant.

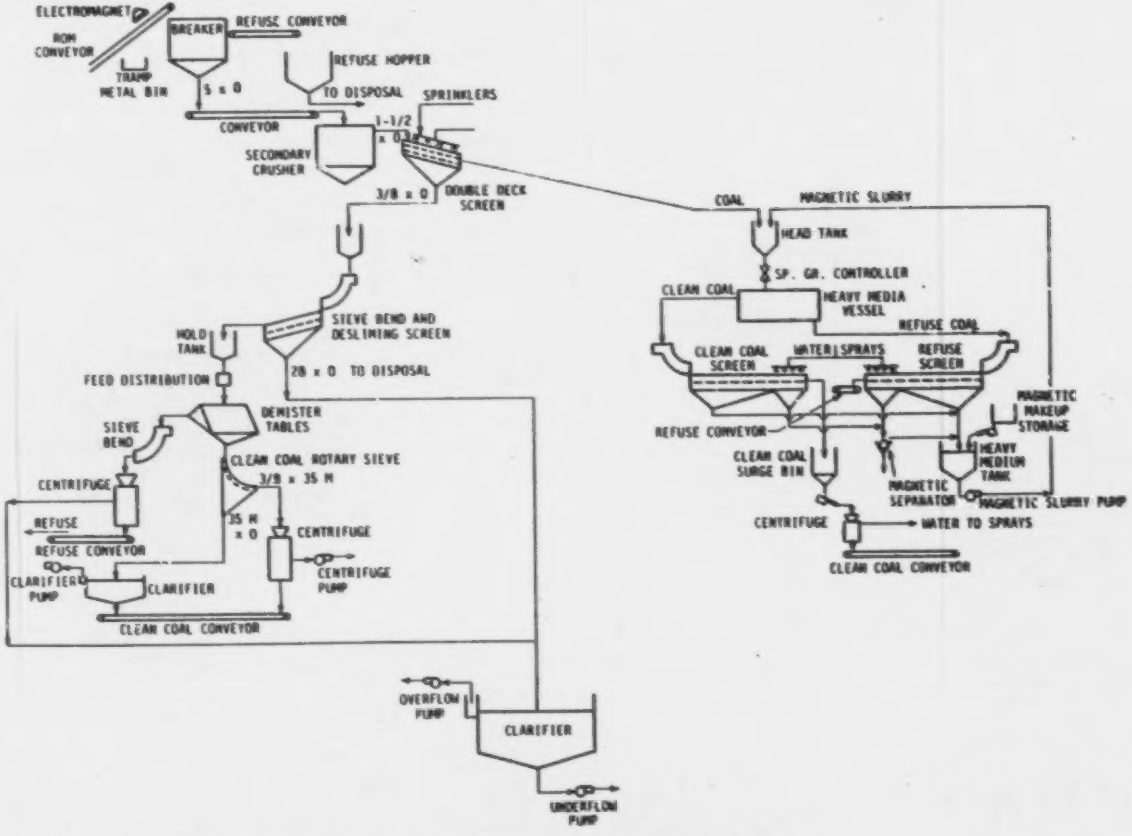
ELECTROMAGNET
ROM CONVEYOR
TRAMP METAL BIN
BREAKER
REFUSE CONVEYOR
REFUSE HOPPER
TO DISPOSAL
5 x 0
CONVEYOR
SECONDARY CRUSHER
1-1/2 x 0
SPRINKLERS
DOUBLE DECK SCREEN
3/8 x 0
COAL
MAGNETIC SLURRY
HEAD TANK
SP. GR. CONTROLLER
CLEAN COAL
HEAVY MEDIA VESSEL
REFUSE COAL
CLEAN COAL SCREEN
WATER SPRAYS
REFUSE SCREEN
MAGNETIC MAKEUP STORAGE
REFUSE CONVEYOR
CLEAN COAL SURGE BIN
HEAVY MEDIUM TANK
MAGNETIC SEPARATOR
MAGNETIC SLURRY PUMP
CENTRIFUGE
WATER TO SPRAYS
CLEAN COAL CONVEYOR
SIEVE BEND AND DESLIMING SCREEN
HOLD TANK
28 x 0 TO DISPOSAL
FEED DISTRIBUTION
DEMISTER TABLES
SIEVE BEND
CLEAN COAL ROTARY SIEVE
3/8 x 35 M
CENTRIFUGE
35 M x 0
CENTRIFUGE
REFUSE
REFUSE CONVEYOR
CENTRIFUGE PUMP
CLARIFIER PUMP
CLARIFIER
CLEAN COAL CONVEYOR
OVERFLOW PUMP
CLARIFIER
UNDERFLOW PUMP

Figure 3-3. Heavy-media and concentrating table coal cleaning plant.

Pittsburgh Seam (Ohio No. 8) primarily from Belmont County, Ohio. Each mine is equipped with a jig preparation plant. The remaining coal was supplied by 16 other mines, 9 of which provide coal with less than 1 percent sulfur. Ohio No. 8 coal from Belmont County can be further cleaned by a heavy-media cyclone plant. Selection of the heavy-media cyclone model for Eastlake was based on the preponderant use of Ohio No. 8 coal at that plant and the low-sulfur content of much of the remaining coal burned there.

For the Eastlake and the other individual plants, the sulfur removal efficiency and Btu recovery factor were determined by review of the published washability data.

The capacity of each cleaning plant is based on the quantity of cleanable coals supplied to each of the 50 power plants. Quantities of cleanable coals identified from the 1979 coal consumption data were adjusted for coal loss in cleaning. The size of each cleaning plant is based on an assumption of 4000 hours/year of operation. The plants are designed for 10 percent excess capacity, and the capacities are rounded to the nearest 50 tons. A minimum capacity of 500 tons/hour was assigned to the plants whose calculated capacities were lower.

From data on sulfur reductions and quantities of cleanable coals, the annual reductions in SO_2 emission were calculated as both quantities and percentages. Table 3-6 summarizes these data.

TABLE 3-6. SUMMARY OF RESULTS OF COAL CLEANING ANALYSIS (1980 dollars)

Plant	Power plant capacity, 10^9 Btu/yr	Coal heating value, Btu/lb	Percent of plant capacity cleaned	Coal cleaning plant type	Sulfur reduction, %	Btu recovery, %	Cleaning plant size, tons/hr	Capital cost		Annual costs[a]			SO_2 emissions		
								$ x 10^6	$/ton	$ x 10^6	$/ton	Mills/kWh	Before cleaning, 10^3 tons	After cleaning, 10^3 tons	Reduction, %
Paradise	120,000	10,600	85.9	1	40	90	1,500	43.08	29,203	36.60	6.10	3.17	396.40	260.20	34.4
Gavin	169,870	9,260	100.0	3	30	95	2,700	62.67	23,210	42.10	3.90	2.60	374.74	262.32	30.0
Muskingum River	80,248	10,430	100.0	3	30	95	1,150	27.96	24,316	19.37	4.21	2.15	370.98	259.69	30.0
Monroe	172,415	12,412	65.3	1	20	95	1,350	39.61	29,338	25.08	4.64	1.39	315.33	274.15	13.1
Cumberland	126,617	10,820	86.3	1	30	90	1,550	45.19	29,158	37.74	6.09	3.42	314.33	232.95	25.9
Clifty Creek	84,173	10,968	100.0	1	20	95	1,150	33.81	29,402	21.66	4.71	2.52	299.34	239.47	20.0
Baldwin	105,881	10,547	99.7	2	20	95	1,450	29.06	20,041	21.38	3.69	1.84	294.14	235.49	19.9
Conesville	78,466	10,808	100.0	2	25	95	1,100	22.08	20,075	16.69	3.79	4.40	293.37	220.03	25.0
Gibson	130,208	10,700	100.0	3	25	95	1,800	42.55	23,641	28.91	4.02	2.38	281.75	211.31	25.0
Labadie	129,339	10,781	59.0	1	10	90	1,100	35.52	29,562	27.46	6.24	2.40	255.07	240.02	5.9
Kyger Creek	70,660	11,242	93.0	3	12	95	850	21.52	25,319	14.64	4.30	2.01	226.03	200.80	11.2
Mitchell	77,610	11,767	80.0	3	15	95	800	20.59	25,736	13.96	4.36	1.45	214.14	188.44	12.0
Brown	146,660	11,728	100.0	3	10	95	1,850	43.56	23,547	29.61	4.00	1.86	209.57	188.61	10.0
Sammis	89,975	11,604	97.0	3	20	95	1,100	26.96	24,507	18.67	4.24	1.88	188.47	151.91	19.4
Hatfield	86,310	11,875	100.0	1	12	95	1,100	32.52	29,562	20.86	4.74	2.13	181.49	159.71	12.0
Petersburg	65,452	10,953	100.0	3	20	95	900	22.52	25,024	15.34	4.26	4.26	177.00	141.60	20.0
New Madrid	61,556	10,584	100.0	1	20	95	850	25.88	30,447	16.34	4.81	2.63	176.63	141.30	20.0
Homer City	124,101	11,667													
Cardinal	99,997	11,543	60.0	2	10	95	800	16.35	20,432	12.31	3.85	1.06	175.12	164.61	6.0
Johnsonville	76,089	11,220	100.0	3	15	95	1,000	24.54	24,544	17.16	4.29	2.59	174.04	147.93	15.0
Gaston	112,217	11,823	45.0	3	15	95	650	17.51	26,942	11.84	4.55	0.95	167.64	156.32	6.8
Wansley	108,116	11,111	56.6	1	20	95	800	24.62	30,771	15.54	4.86	1.41	164.36	145.75	11.3
Eastlake	62,006	12,169	67.1	1	25	90	550	18.47	33,584	14.88	6.76	2.53	161.23	134.18	16.8
Harrison	83,015	12,666	55.4	1	10	95	550	18.47	33,584	11.50	5.26	1.32	159.24	150.42	5.5
Coffeen	45,309	9,263	87.7	1	30	95	650	20.87	32,114	13.15	5.06	3.10	159.00	117.17	26.3
Brunner Island	87,980	12,497	100.0	1	10	95	1,050	31.27	29,785	20.06	4.78	1.95	158.67	142.80	10.0
Kammer	47,450	11,792	90.9	3	20	90	600	16.48	27,462	14.73	6.14	3.07	151.81	124.21	18.2
Kincaid	55,845	10,147	67.5	1	10	95	550	18.47	33,584	11.58	5.26	2.47	150.77	140.59	6.8
Warrick	53,898	11,045	76.6	1	20	95	550	18.47	33,584	11.58	5.26	2.57	144.12	122.04	15.3
Keystone	90,072	11,836	84.2	3	25	95	950	23.56	24,802	16.04	4.22	1.48	140.23	110.71	21.0
Stuart	141,504	11,173	26.1	1	10	95	500	17.17	34,348	10.77	5.39	0.78	135.34	131.81	2.6
Cayuga	57,999	10,289	78.0	2	25	95	650	13.98	21,505	10.48	4.03	1.72	135.19	108.83	19.5
Montour	96,988	12,507	100.0	3	30	95	1,150	27.96	24,316	19.37	4.21	1.84	127.30	89.11	30.0

(continued)

TABLE 3-6 (continued)

Plant	Power plant capacity, 10^9 Btu/yr	Coal heating value, Btu/lb	Percent of plant capacity cleaned	Coal cleaning plant type	Sulfur reduction, %	Btu recovery, %	Cleaning plant size, tons/hr	Capital cost		Annual costs[a]			SO_2 emissions		
								$ x 10^6	$/ton	$ x 10^6	$/ton	Mills/kWh	Before cleaning, 10^3 tons	After cleaning, 10^3 tons	Reduction, %
Shawnee	93,150	11,860	41.0	1	10	95	500	17.17	34,348	10.77	5.39	1.40	126.44	121.26	4.1
Gallatin	85,076	11,890	100.0	3	10	95	1,050	25.75	24,526	17.92	4.27	2.71	122.43	110.19	10.0
Thomas Hill	30,195	9,760	100.0	2	30	90	500	11.54	23,072	11.62	5.81	4.23	119.96	83.97	30.0
Conemaugh	67,554	12,136	100.0	2	25	95	850	17.08	20,100	12.91	3.80	1.82	119.66	89.74	25.0
Amos	165,466	11,840	100.0	1	10	95	2,050	57.86	28,222	36.46	4.45	1.70	117.24	105.52	10.0
Avon Lake	55,177	11,953	81.0	1	25	95	550	18.47	33,584	11.58	5.26	2.24	116.48	92.89	20.2
Beckjord	55,452	10,753	100.0	1	15	95	750	23.53	31,369	14.78	4.93	2.47	116.26	98.82	15.0
Joppa	71,418	11,577	100.0	1	10	95	900	27.20	30,222	17.16	4.77	2.40	115.60	104.04	10.0
Cobb	38,185	11,199	50.0	1	20	95	500	17.17	34,348	10.77	5.39	3.05	114.56	103.10	10.0
Miami Fort	66,771	11,371	100.0	1	20	95	850	25.88	30,447	16.34	4.81	2.59	108.95	87.16	20.0
Fort Martin	71,243	12,113	100.0	1	15	95	900	27.20	30,222	17.16	4.77	2.41	107.14	91.07	15.0
Kingston	130,782	11,550	100.0	1	20	95	1,650	47.96	29,068	30.11	4.56	3.35	106.00	84.80	20.0
Colbert	59,548	11,500	62.8	1	15	95	550	18.47	33,584	11.58	5.26	1.99	102.32	92.68	9.4
Oak Creek	62,069	11,440	50.0	1	25	95	500	17.17	34,348	10.77	5.39	1.51	101.47	88.79	12.5
Big Bend	56,334	11,475	63.2	1	15	95	500	17.17	34,348	10.77	5.39	1.73	99.56	90.12	9.5
Sioux	50,127	10,206	55.4	1	15	95	500	17.17	34,348	10.77	5.39	2.12	98.84	90.63	8.3

[a] Includes replacement coal costs for coal lost through cleaning.

Coal Cleaning Costs

Cost equations for each of the three cleaning plant configurations provide capital and annual operating costs for the cleaning plants as a function of plant size. Capital costs include cost of the plant equipment, installation costs, and associated indirect costs. Annual operating costs include the costs of operation, capital recovery charges, and costs of coal lost in cleaning.

Capital and annual costs of various size coal cleaning plants were applied to the three model plant configurations. The program calculated various stream quantities and sized the plant equipment accordingly. The program also applied cost equations for individual equipment items as a function of equipment size to yield specific equipment costs for each of the 50 power plants. Total capital costs were calculated by adding the indirect costs and contingencies.

The program also computed annual costs based on equations for raw materials, utilities, and labor. The fixed charges (function of total capital cost) were then added to give a total annual cost for each plant.

The model incorporates the following assumptions:

- The cleaning plant is located at the power plant site.
- Cleaning plant refuse is diposed of on site.
- The cleaning plant operates 4000 hours/year.
- The base year for costs is 1980.

Table 3-6, which summarizes the results of the entire coal cleaning analysis for the 50 major SO_2 emitters, shows capital and annual costs for each of these plants. The analysis does not include costs for the Homer City or Mansfield plants. The Homer City plant currently fires physically cleaned coal, for which no further emission reductions would be achieved by additional cleaning. The Mansfield plant uses flue gas desulfurization.

After implementation of coal cleaning, the annual SO_2 emissions from the 50 plants would total 7,129 x 10^3 tons, representing an overall SO_2 emission reduction of 17 percent. The estimated total capital cost of coal cleaning is at $1.3 billion; estimated total annual operating costs are $869 million.

3.3 FLUE GAS DESULFURIZATION

Wet flue gas desulfurization (FGD) systems provide a reliable, high efficient means of controlling SO_2 emissions from utility boilers. Control efficiencies are as high as 90 percent over a wide range of coal types. Although several FGD processes are currently available, wet systems that use limestone or lime as the SO_2 absorbent dominate the utility FGD market. The primary advantage of these systems is the low cost of the absorbent. The limestone and lime systems are nonregenerable, producing large quantities of sludge that must be properly disposed of.

The following analysis is based on the wet limestone FGD process, which is the most highly developed commercial FGD system. In June 1980, limestone systems represented 45.1 percent of the total domestic FGD capacity. Table 3-7 shows the current status of FGD systems in the United States. Table 3-8 shows the capacities of current and predicted nonregenerable FGD systems.

System Description

A process diagram of the limestone FGD system used in this analysis is shown in Figure 3-4. The system includes four major operational areas:

1. Limestone handling and slurry preparation, which includes limestone unloading and storage equipment and the feed preparation equipment such as ball mills, conveyors, slurry storage tanks, and supply pumps.
2. Flue gas handling, which includes necessary ductwork, fan, valves, and reheaters.
3. SO_2 scrubbing, which includes SO_2 absorbers, recycle pumps, and holding tanks.
4. Sludge processing, which includes all equipment for sludge dewatering and stabilization, such as clarifiers, vacuum filters, and fixation tanks.

A forced-draft fan forces the flue gas from the boiler through the SO_2 absorber via the connecting ductwork. The absorber is designed to promote intimate contact between the flue gas and the circulating reagent slurry. The SO_2 in the flue gas and calcium in the slurry react to form nonsoluble calcium compounds. The calcium compounds are removed in a bleed stream and sent to disposal through the sludge dewatering and fixation circuit.

TABLE 3-7. STATUS OF U.S. FGD SYSTEMS

Status	All systems		Nonregenerable systems	
	No.	Controlled capacity,[a] MW	No.	Controlled capacity, MW
Operational	73	24,765	65	23,166
Under construction	38	16,524	34	15,316
Planned	89	49,473	59	31,643
Total	200	90,762	158	70,125

[a] Controlled capacity is the total scrubbed flue gas volume, converted to equivalent MW and based on the percentages of flue gas scrubbed by each FGD system.

TABLE 3-8. PROJECTED CAPACITIES OF NONREGENERABLE FGD SYSTEMS

	Portion of total controlled capacity in June 1980, %	Projected portion of total controlled capacity in December 1990, %
Wet systems		
Limestone	45.1	37.9
Lime	39.8	23.0
Sodium		
Dual-alkali	4.8	2.2
Other	3.8	7.9
Dry systems		
Lime	0	3.3
Aqueous carbonate	0	0.5

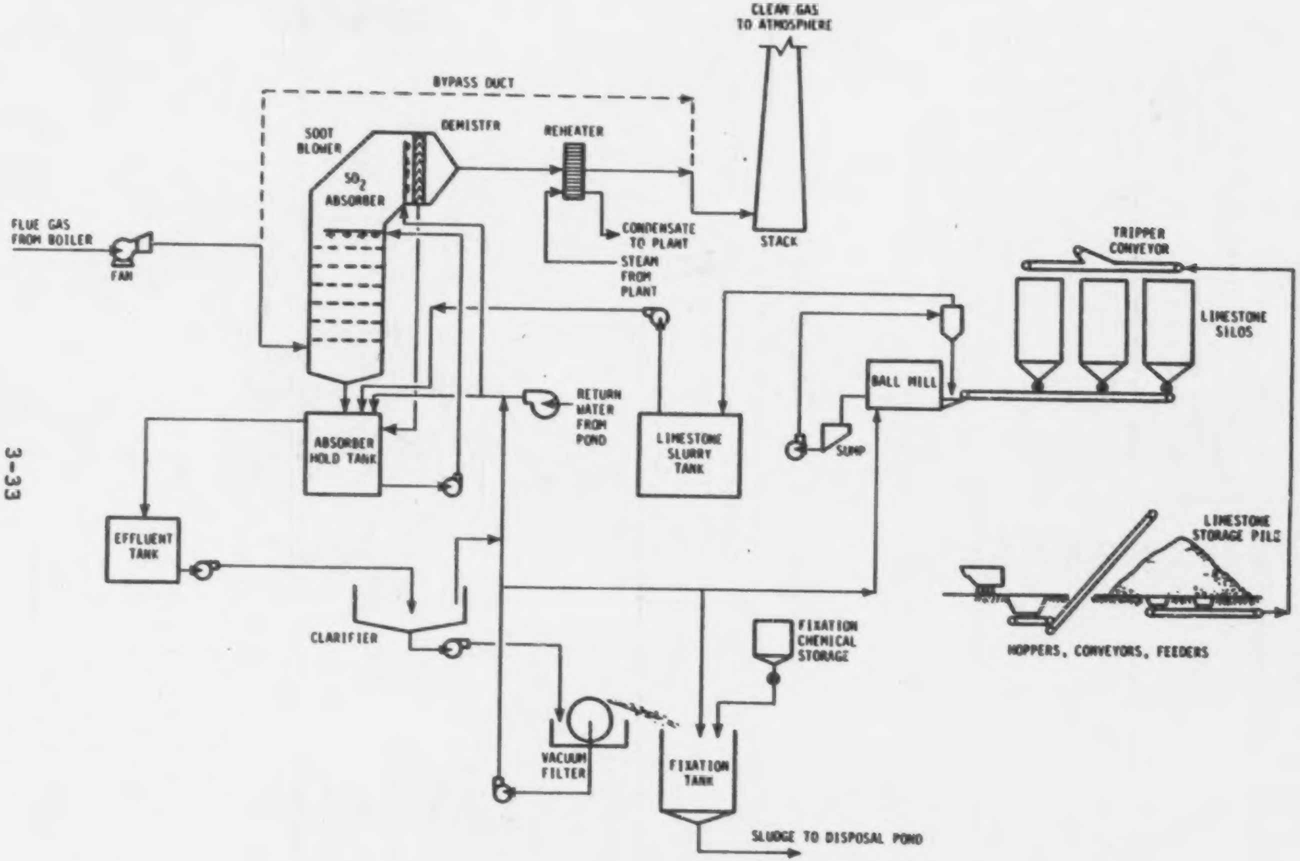
CLEAN GAS TO ATMOSPHERE
BYPASS DUCT
SOOT BLOWER
DEMISTER
REHEATER
SO_2 ABSORBER
FLUE GAS FROM BOILER
FAN
CONDENSATE TO PLANT
STEAM FROM PLANT
STACK
TRIPPER CONVEYOR
LIMESTONE SILOS
BALL MILL
RETURN WATER FROM POND
ABSORBER HOLD TANK
LIMESTONE SLURRY TANK
SUMP
EFFLUENT TANK
LIMESTONE STORAGE PILE
CLARIFIER
FIXATION CHEMICAL STORAGE
HOPPERS, CONVEYORS, FEEDERS
VACUUM FILTER
FIXATION TANK
SLUDGE TO DISPOSAL POND

Figure 3-4. Typical limestone nonregenerable FGD system.

FGD Retrofit Requirements

The 50 major SO_2 emitters analyzed in this study are operating plants, at which the existing plant facilities would impose constraints on installation of FGD equipment. Retrofitting often involves higher capital costs than does the installation of comparable systems at new power plants. A major factor affecting the costs of retrofit FGD systems is the lack of space for SO_2 absorbers in the vicinity of the stack and economizer.

Ideally, the SO_2 absorber is located between the existing electrostatic precipitator (ESP) and the stack, so that no long duct runs are needed. At most plants, however, the compact layout provides little space near the stack, and ducting must be added to connect the absorbers to the boiler system. Support facilities, such as those for feed preparation and sludge treatment, can be installed away from the stack, usually without significant cost.

Retrofit problems are accounted for in FGD cost estimates for the individual plants. For cost estimation, each plant is classified in one of the following three categories, based on degree of retrofit difficulty:

- Easy retrofit: Adequate space is available near the stack and ESP for locating FGD scrubbing equipment without long duct runs. Adequate space is available near the stack and boiler room for FGD support facilities. No major relocation of plant facilities is required.
- Difficult retrofit: Little or no space is available for scrubbing equipment between the stack and ESP, and long duct runs are needed. Adequate space is available for support facilities.

- Extremely difficult retrofit: Severe space constraints necessitate major relocation of plant facilities, long duct runs, and major FGD design changes.

Information on layout at each of the 50 plants provided a basis for classifying each plant into a retrofit category and for estimating the length of duct runs needed for FGD equipment. The computer model then estimated FGD costs for each plant, with retrofit factor and duct runs as variables.

FGD Cost Model

The PEDCo FGD cost model, originally developed in 1976, was updated for this analysis to reflect the current FGD system trends and current equipment costs. The computer model can generate capital and annual operating costs for limestone- and/or lime-based FGD systems.

Input for the model consists of plant design and operating parameters and manpower and utilities cost parameters. The program first calculates a material balance for the system, then determines equipment sizes and quantities by use of sizing equations. The program then generates equipment costs, based on current cost data provided by vendors. Costs of labor and materials for installation of each item are then added to provide total direct costs. Indirect costs are calculated as percentages of the direct costs. The program calculates operating costs as a function of reagent and utility prices and estimated usage rates. The labor costs, maintenance costs, and ammortization charges are then added to obtain the total annual operating costs.

Input for the model consists of such information as fuel data, SO_2 removal efficiency, boiler gas flows, boiler capacity factors, and duct requirements. Rate data include costs of electricity, water, fuel, labor, and capital. The base year for costs is 1980, but capital costs can be adjusted to a different year.

Generation of Data Base for FGD Costs

Generation of realistic FGD costs required current information from each of the 50 plants. The major information sources were the DOE forms FPC-67 and FPC-423. The FPC-67 form gives information on number of boilers, capacities, capacity factors, installation date, and emission control status. The FPC-423 forms give information on the quality, quantity, and cost of fuel used at each plant.

Current data from these DOE forms were compared with plant data obtained from other sources. A problem with the FPC-67 data was that the design flue gas flow rates were consistently lower than actual operating flow rates. The operational FGD systems generally report gas flow rates around 3600 acfm/MW, with a lower limit of 3200 acfm/MW. The FPC-67 forms for the 50 high-emission plants, however, showed the following:

Gas flow rate, acfm/MW	Percent of boiler population
<2500	2
<2700	13
<3000	45
<3200	65
<3500	78
<4000	92

Because FGD costs are highly sensitive to the gas flow rates, each of the 50 plants was queried regarding actual operating flue gas rate and temperature. The operating values cited in responses were generally higher than the design gas flow rates. By way of comparison, Table 3-9 shows design gas flow rate and temperature data from FPC-67 forms and the operating data provided by several TVA plants.

Most of the retrofit factors were obtained by review of plant layout diagrams. Some were based on discussions with responsible plant personnel. A few, which were used where no plant layout was available, were derived by pairing boiler types and installation dates with those at similar plants providing sufficient layout information.

SO_2 Control Levels

Limestone FGD costs were calculated for SO_2 control levels of 90 and 60 percent. The 90 percent level represents an upper efficiency limit for a limestone FGD system. The 60 percent level indicates the cost effectiveness of an FGD system at lower efficiencies.

The cost model, designed for maximum SO_2 removal efficiency of 85 percent, was modified to handle systems yielding 90 percent SO_2 removal efficiency on a continuous basis. The major modifications include: (1) addition of one stage to the SO_2 absorber, (2) a higher-capacity fan to accommodate pressure drop in the additional absorbing stage, and (3) modifications of the absorber recycle pumps and tanks.

TABLE 3-9. GAS FLOW RATES AT TVA PLANTS

Plant and boiler	Capacity, MW	FPC-67 data		Actual data supplied by TVA		Flow rate, acfm/MW at 300°F	
		Flow, acfm	Temp., °F	Flow, acfm	Temp., °F	FPC-67	Supplied by TVA
Paradise 1 and 2	1408	3,580,000	290	4,220,000	175	2580	3590
Paradise 3	1750	2,898,000	303	3,850,000	286	2510	3410
Cumberland 1 and 2	2600	7,200,000	290	9,760,000	300	2810	3750
Johnsonville 1 through 10	1486	4,176,000	290	5,480,000	280	2850	3790
Shawnee 1 through 10	1750	4,379,000	308	6,100,000	285	2480	3560
Gallatin 1 and 2	600	1,466,000	300	2,010,000	272	2440	3480
Gallatin 3 and 4	656	1,694,000	290	2,182,000	253	2620	3550
Kingston 1 through 5	900	2,304,000	306	3,412,600	300	2540	3790
Kingston 6 through 9	823	2,300,000	300	3,103,500	300	2790	3770
Colbert 1 through 4	869	2,274,400	292	3,452,000	350	2640	3730

The cost estimates for 60 percent control are based on partial scrubbing of the flue gas stream. The FGD system operates at full design efficiency of 85 percent, but the system is designed to treat only about 71 percent of the flue gas. The remainder bypasses the FGD system and joins the clean stream from the FGD process just before entering the stack. This arrangement reduces the costs of equipment for flue gas handling, reagent preparation, and sludge processing. The untreated portion of the gas stream provides heat that greatly reduces and sometimes totally eliminates reheat requirements. The computer program automatically calculates whether reheat is required, and any necessary reheat increment.

Limestone FGD Costs

Limestone FGD costs for 90 percent and 60 percent SO_2 removal at the 50 plants are shown in Table 3-10. No FGD costs are shown for the Bruce Mansfield plant, which is equipped with FGD. Some of the boilers at the Conesville and Petersburg plants are FGD-controlled, and costs are adjusted accordingly.

The estimated total capital cost for 90 percent SO_2 control at the 50 plants is to be $11 billion. The corresponding total annual cost is estimated at $3.6 billion. On the basis of 1979 emission estimates, 90 percent control will reduce SO_2 emissions from 8.6 million tons/yr to 0.9 million tons/yr.

The estimated total capital cost of 60 percent SO_2 control at the 50 plants with partial scrubbing is to be $6.9 billion. The total annual cost is $2.2 billion. On the basis of 1979

TABLE 3-10. SUMMARY OF CAPITAL AND ANNUAL COSTS OF LIMESTONE FGD SYSTEMS (1980 dollars)

Plant name	No. of boilers	Plant capacity	90 % control				60 % control			
			Capital		Annual		Capital		Annual	
			$ x 10^6	$/kW	$ x 10^6	mills/kWh	$ x 10^6	$/kW	$ x 10^6	mills/kWh
Paradise	3	2558	336.40	131.52	106.44	9.18	215.26	84.16	68.00	5.95
Gavin	2	2600	288.44	110.94	99.48	6.11	174.00	66.93	60.52	3.72
Muskingum River	5	1530	230.50	150.66	83.36	9.25	144.29	94.31	52.58	5.84
Monroe	4	3280	467.18	142.44	150.06	8.35	289.27	88.20	93.70	5.22
Cumberland	2	2600	332.26	127.80	102.46	9.37	198.26	76.26	62.02	5.67
Clifty Creek	6	1304	243.64	186.85	89.25	10.35	152.63	117.05	56.08	6.50
Baldwin	3	1892	249.75	132.01	89.88	7.71	153.86	81.33	55.47	4.76
Conesville	2	1191	194.00	162.89	59.76	13.01	118.73	99.70	37.13	8.08
Gibson	4	2672	359.13	134.41	113.24	9.30	219.42	82.12	69.24	5.69
Labadie	4	2220	286.66	129.13	92.51	8.10	173.12	77.99	56.30	4.93
Kyger Creek	5	1086	199.76	183.94	73.06	10.05	124.02	114.21	45.41	6.25
Mitchell	2	1632	216.31	132.55	70.66	7.38	132.27	81.05	43.77	4.57
Bowen	4	3160	379.44	120.08	123.28	7.73	231.81	73.36	75.64	4.74
Sammis	7	2304	342.62	148.71	100.51	10.14	221.07	95.96	64.81	6.54
Hatfield	3	1728	211.41	122.35	72.15	7.37	126.94	73.47	43.74	4.47
Petersburg	2	724	99.21	137.03	31.93	8.88	62.81	86.76	20.34	5.66
New Madrid	2	1200	141.54	117.96	49.07	7.91	87.74	73.12	30.56	4.93
Homer City	3	1850	281.56	152.20	94.28	7.26	173.34	93.70	58.32	4.49
Cardinal	3	1880	265.26	141.10	85.40	7.31	161.55	85.94	52.18	4.47
Johnsonville	10	1485	208.21	140.22	69.89	10.59	126.63	85.28	43.23	6.55
Gaston	5	2013	344.15	170.97	108.98	8.74	217.50	108.05	68.74	5.51
Wansley	2	1730	194.16	112.23	68.82	6.26	117.12	67.70	41.93	3.82
Eastlake	3	1257	197.73	157.31	61.93	11.05	124.84	99.32	39.11	6.98
Harrison	3	2052	251.26	122.45	75.96	8.68	155.34	75.71	47.46	5.42
Coffeen	2	1006	155.53	154.61	50.08	11.83	97.48	96.91	31.38	7.41
Brunner Island	3	1558	206.19	132.35	71.05	6.90	128.22	82.30	44.04	4.28
Kammer	3	714	126.17	176.71	42.95	8.92	79.95	111.97	27.30	5.67
Kincaid	2	1320	155.64	117.92	49.57	10.59	97.43	73.82	31.00	6.62
Warrick	4	732	131.51	179.67	42.97	9.53	86.55	118.24	27.97	6.21
Keystone	2	1872	223.52	119.40	73.36	6.73	134.76	71.99	44.73	4.10
Stuart	4	2441	314.36	128.78	95.51	6.94	195.69	80.17	59.11	4.29
Cayuga	2	1062	127.79	120.33	43.84	7.19	78.99	74.38	27.24	4.47
Montour	2	1534	176.32	114.95	62.53	5.97	108.56	70.78	38.62	3.68
Shawnee	10	1750	244.08	139.48	79.34	10.33	160.01	91.44	51.94	6.76
Gallatin	4	1256	201.25	160.24	62.45	9.42	134.02	106.70	41.32	6.23
Thomas Hill	2	480	82.54	171.97	29.09	10.54	54.02	112.55	19.03	6.90
Conemaugh	2	1872	228.09	121.85	68.65	9.74	138.48	73.98	42.19	5.90
Amos	3	2932	317.30	108.22	100.81	4.70	188.75	64.38	60.06	2.80
Avon Lake	4	1085	197.33	181.87	59.68	11.52	127.86	117.84	38.63	7.45
Beckjord	6	1162	201.83	173.69	61.99	10.43	129.52	111.47	39.55	6.65
Joppa	6	1086	153.95	141.76	59.28	8.27	100.94	92.95	38.08	5.31
Cobb	5	510	80.83	158.50	33.33	9.46	51.40	100.79	21.18	6.01
Miami Fort	4	1292	190.68	147.59	58.91	9.27	117.54	90.98	36.63	5.76
Ft. Martin	2	1152	136.00	118.06	43.40	6.10	84.42	73.28	26.97	3.79
Kingston	9	1723	288.55	167.47	92.50	9.37	181.73	105.48	58.16	5.89
Colbert	5	1419	215.48	151.86	66.43	11.51	132.94	93.69	41.23	7.14
Oak Creek	8	1670	250.03	149.73	77.32	10.71	163.44	97.88	50.57	7.00
Big Bend	3	1338	167.07	124.87	53.81	8.66	107.01	79.98	34.11	5.49
Sioux	2	1100	144.75	131.60	43.91	8.68	89.22	81.11	27.04	5.35

emission estimates, 60 percent SO_2 control at the 50 plants will reduce SO_2 emissions from 8.6 million tons/yr to 3,453 x 10^3 tons/yr.

A more detailed analysis of capital and annual costs is presented in Appendix B.

3.4 DRY FLUE GAS DESULFURIZATION

A dry FGD process generates dry waste for disposal, rather than a sludge. There are three major types of dry FGD systems, based on spray drying, dry injection, and combustion of fuel/limestone mixtures. Only the spray drying process is used on a commercial scale,[3] and thus this process is discussed here. Several manufacturers offer spray dry scrubbing systems:

- Babcock and Wilcox
- Carborundum
- Rockwell
- Joy/Niro
- Combustion Engineering
- Research Cottrell
- Koch

Although no full-scale dry FGD utility system is yet operating, several are planned or under construction. Table 3-11 gives information on these systems.

Several vendors offer spray drying systems of similar general design. The absorbent (usually lime or soda ash), blended in a slurry (or solution), is injected at the top of a spray dryer and is atomized into very fine droplets. As the droplets contact the flue gas, the heat of the gas stream dries the droplets, which absorb SO_2. The resulting dry product consists of calcium sulfates, sulfites, unreacted absorbent, and

TABLE 3-11. UTILITY DRY SCRUBBING SYSTEMS, PLANNED OR UNDER CONSTRUCTION

Utility	Plant/unit	Coal sulfur content, %	SO_2 removal efficiency, %	Startup date
Basin Electric Power Coop.	Laramie River 3	0.54	82.5	4/82
Montana-Dakota Utilities Co.	Coyote 1	0.87	70.0	3/81
Niagara Mohawk Power Corp.	Huntley 66	1.80	90.0	4/82
Basin Electric Power Coop.	Antelope Valley 1	0.68	60.0	4/83
Colorado Ute Electric Assn., Inc.	Craig 3	0.45	85.0	1982
Northern States Power Co.	Riverside 6 & 7	1.20	90.0	11/80
Tuscon Gas & Electric Co.	Springerville 1	0.61	70.0	1/85
Tuscon Gas & Electric Co.	Springerville 2	0.61	70.0	3/87
United Power Assn.	Stanton 1A	0.77	72.7	6/82
Sunflower Electric Coop, Inc.	Holcomb 1	0.97	80.0	9/83
Marquette Board of Light & Power	Shires 3	NA	70.0	8/84
Platte River Power Authority	Rawhide 1	0.25	88.0	12/83
Sierra Pacific Power Co.	Valmy 2	NA	70.0	8/84

N/A - Not available.

fly ash. The greater portion passes with the flue gas stream to a particulate control device (fabric filter or ESP), for removal by the ash disposal system. Additional reaction with SO_2 may occur on the bag surface of a fabric filter.

The system analyzed here uses a fabric filter and a recycle system, which reslurries and reinjects part of the collected material, thus improving absorbent utilization. Figure 3-5 shows a typical dry FGD process diagram with a recycle system. Recycling offers three advantages:[4]

1. It utilizes unreacted lime.
2. It provides reactive surface area through reatomization.
3. It can improve SO_2 removal by fly ash alkalinity.

The alkalinity of fly ash constituents (K_2O, Na_2O, CaO, and MgO) can aid significantly in SO_2 absorption. Manufacturers of dry FGD systems depend upon fly ash alkalinity to minimize the lime requirements and to maximize lime and fly ash utilization. Lignitic coals characteristically contain high proportions of these compounds.[5] Subbituminous coals, however, may contain only half as much as the lignites. Thus, although recycling improves utilization, systems operating on flue gas from subbituminous costs require more fresh lime per pound of SO_2 removed. Eastern bituminous coals usually contain even less alkaline materials than subbituminous or lignite coals,[5] and the role of recycling diminishes correspondingly. Table 3-12 indicates typical lime stoichiometric requirements for different types of coal.

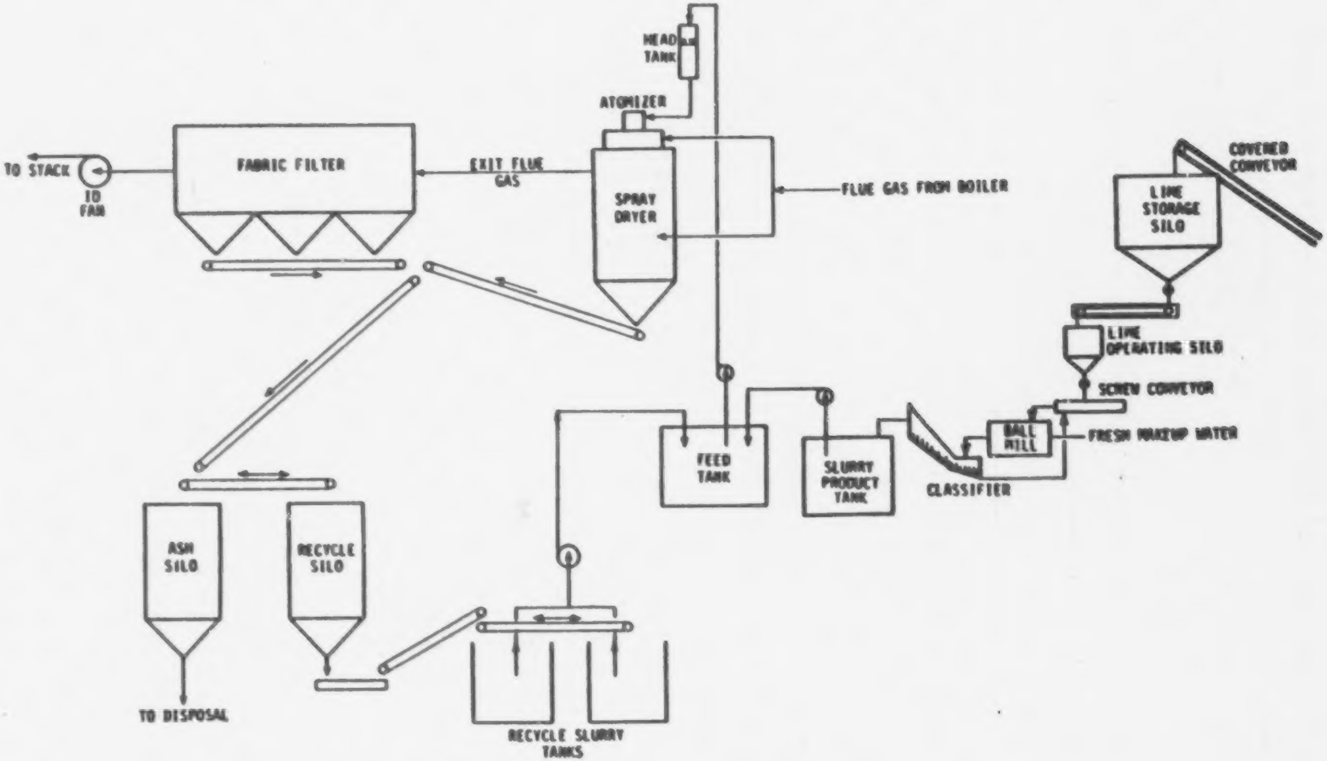
HEAD TANK
ATOMIZER
TO STACK
ID FAN
FABRIC FILTER
EXIT FLUE GAS
SPRAY DRYER
FLUE GAS FROM BOILER
COVERED CONVEYOR
LIME STORAGE SILO
LIME OPERATING SILO
SCREW CONVEYOR
BALL MILL
FRESH MAKEUP WATER
FEED TANK
SLURRY PRODUCT TANK
CLASSIFIER
ASH SILO
RECYCLE SILO
TO DISPOSAL
RECYCLE SLURRY TANKS

Figure 3-5. Typical dry FGD process with a recycle system.

TABLE 3-12. TYPICAL LIME STOICHIOMETRIC RATIOS FOR DIFFERENT COAL TYPES[6,7,8]

Coal type	Stoichiometric ratio
Lignite	1.3 - 1.7
Subbituminous	1.8 - 2.2
Bituminous	2.0 - 2.8

Because the lime requirements are very coal-specific, some FGD system vendors will issue bids only after testing a sample of the coal or fly ash.

Dry FGD processes offer several advantages over wet scrubbing. The vessels and ductwork of dry systems can be constructed of low-carbon steel, whereas those of wet systems often require special materials or coatings to prevent corrosion or erosion. Because no wet materials contact the walls of a dry scrubber, scaling and plugging do not occur. Also, because the product is dry, no sludge handling equipment is needed.

Dry scrubbing technology was developed primarily to achieve 70 percent SO_2 removal efficiency at sources burning low-sulfur western coal. Spray dryer systems do achieve that efficiency and are accepted by the utilities. Moreover, as much as 90 percent SO_2 removal has been reported in pilot tests with 3.5 percent sulfur coal. In spite of these successes, however, dry scrubbing is not regarded as competitive with wet FGD systems when sulfur content of the coal approaches 2 percent. Further, only limited amounts of slurry and dilution water may be atomized in a standard-size spray dryer and still yield a dried product. The fresh lime requirement increases with inlet SO_2

concentration. Joy/Niro has experimented with slurries of up to 50 percent solids to identify settling and handling problems. Most dry scrubbing systems, however, use slurries of 30 to 35 percent solids. Complete drying of the slurry then depends on inlet flue gas temperature, residence time, and atomization of the slurry.

Of the 50 largest uncontrolled SO_2 emitters (Table 2-2), several plants fire bituminous coal containing less than 2 percent sulfur. So as to ensure 90 percent SO_2 removal efficiency for the dry FGD cost analysis, spray drying systems were applied only to those plants using coals with less than 1.5 percent sulfur, i.e., the Stuart, Amos, and Kingston power plants.

Basic design criteria for a dry FGD system were based on information provided by Joy/Niro, Babcock and Wilcox, Combustion Engineering, and Carborundum. Essentially the spray dryer configuration consists of a compound gas disperser with a single rotary atomizer, as shown in Figure 3-6. The system recycles collected particulate and uses a fabric filter for control of stack emissions. The module is sized for a 10- to 12-second residence time to permit SO_2 absorption and drying of the particles. It is constructed of 3/8-in. carbon steel, with no special alloys. Only the atomizer wheel assembly incorporates wear-resistant metal. Large-diameter wheel openings (3/4 in.) are designed to prevent plugging. Wheel inserts may be turned periodically to ensure even wear and are expected to last 4000

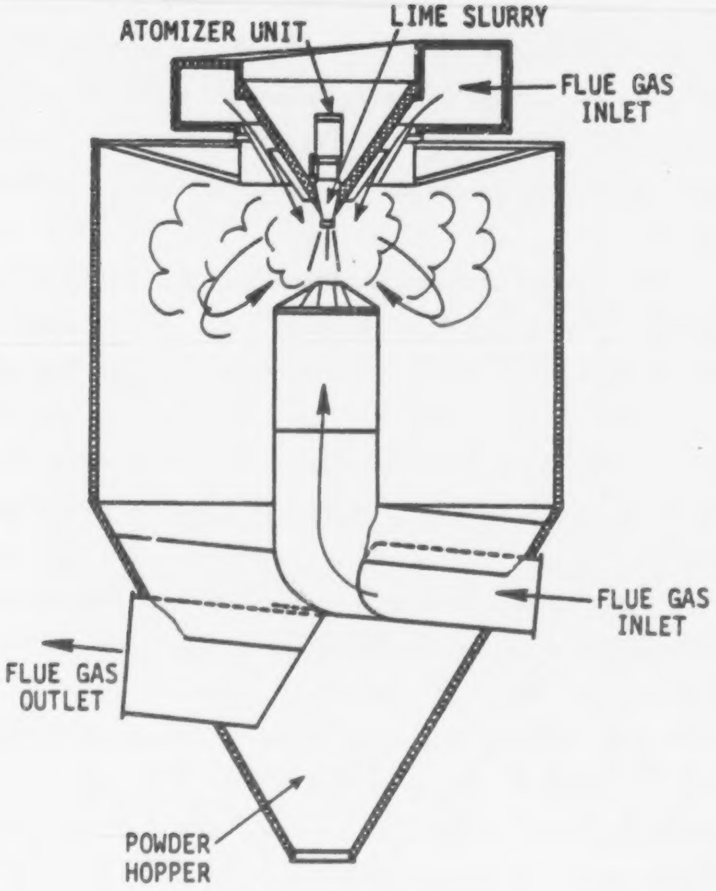
ATOMIZER UNIT
LIME SLURRY
FLUE GAS INLET
FLUE GAS INLET
FLUE GAS OUTLET
POWDER HOPPER

Figure 3-6. Spray dryer module.

Source: Niro Atomizer, Inc./Joy Manufacturing Co.[6]

to 8000 hours. The wheel assembly is expected to last for the life of the power plant.[10]

Estimates of spray dryer costs are based on literature review and discussions with vendors, as are fabric filter cost estimates. Most of the other equipment in a dry FGD system is similar to that in wet FGD systems, i.e., the equipment for lime preparation, flue gas handling, and recycle. Therefore, the cost data described in Section 3.3 also serve as a basis for cost estimates for this equipment and its installation.

The design applied to these three plants includes an integrated lime handling, storage, and slurry preparation system. For high reliability, the spray dryers and associated fabric filters were designed on a per-boiler basis. For Amos and Stuart, the system includes multiple standard spray dryers capable of handling 500,000 to 550,000 acfm at 300°F. For Kingston, each boiler is equipped with two spray dryers, smaller than the standard module. Ducting requirements at Kingston preclude the use of existing ESP's for particulate control.

Particulate material from the spray dryers and fabric filters is conveyed to recycle bins and ash disposal silos. About 55 percent is reslurried and atomized and the remainder is stored for subsequent disposal.

Capital and annual costs are given in Table 3-13. Detailed breakdowns of the cost components for each plant are presented in Appendix C.

TABLE 3-13. DRY SCRUBBING COST ESTIMATES FOR STUART, AMOS, AND KINGSTON POWER PLANTS

	SO_2 removal, %	Capital costs, $ \times 10^6$	Capital costs, $/kW	Annualized costs, $ \times 10^6$/yr	Annualized costs, mills/kWh
Stuart	90	226.93	93.00	76.72	5.57
Amos	90	248.25	84.67	88.94	4.14
Kingston	90	193.18	112.12	70.86	7.22

Since dry scrubbing was only applicable to three of the fifty plants analyzed in this study, a reduction of only 3.7 percent in uncontrolled SO_2 emissions would be realized from application of this strategy.

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SECTION 4

NO_x CONTROL STRATEGIES

Among the stationary sources of NO_x emissions, fossil-fuel-fired utility boilers constitute the largest single contributing sector; in 1977 these boilers generated almost 55 percent of all NO_x emissions from stationary fuel combustion sources and about 31 percent of the total NO_x emissions in the United States.[1] Within the utility category, coal-fired boilers account for over 80 percent of the NO_x emissions.[2] Emissions of NO_x from utility boilers are expected to pose a more severe problem in the future, with a projected increase in construction of new, coal-fired boilers. In view of their predominant present and future impacts on NO_x emissions, the following discussion deals with coal-fired utility boilers and focuses on the 50 largest uncontrolled NO_x emitters identified in Section 2.

The AP-42 emission factors were used in estimating uncontrolled NO_x emissions listed in Section 2. Emission factors from other sources,[4,5,6] also considered for use in this analysis, are expressed as NO_x emissions per unit of heat input. The AP-42 factors, however, are a function of the type of boiler and of fuel properties. Uncontrolled NO_x emissions are estimated by applying the appropriate emission factor to the quantity of coal consumed. For this analysis it was assumed that all of the coal fired by utility boilers in the states that were investigated is bituminous coal. Three different NO_x emission factors were applied to the three different types of utility boilers reported to be in use: pulverized-coal-fired, wet-bottom boilers; pulverized-coal-fired, dry-bottom boilers; and cyclone boilers.

4.1 NO_x CONTROL TECHNIQUES

Formation of NO_x in combustion processes is caused either by thermal fixation of atmospheric nitrogen in the combustion air, which produces "thermal NO_x," or by the conversion of chemically bound nitrogen in the fuel, which produces "fuel NO_x." The relative magnitude and importance of the two modes of NO_x formation varies with the type of fuel used. In coal-fired boilers, fuel NO_x predominates.[4] The control techniques for coal-fired boilers therefore are generally designed to reduce fuel NO_x formation, which depends primarily on oxygen concentration and not so much on temperature.

The principal options for control of NO_x from utility boilers consist of combustion modification, flue gas treatment, and fuel modifications. Among these three options, modifying the combustion conditions is the most effective and widely used technique, achieving moderate (20 to 60 percent) reductions of combustion-generated NO_x.[2] In an effort toward greater levels of control, additional control techniques such as advanced burner/furnace designs and ammonia injection are under development.[7]

Several combustion modification techniques may be used singly or in combination on coal-fired utility boilers. These include low excess air (LEA) firing; staged or off-stoichiometric combustion (OSC) implemented through biased burner firing (BBF), burners out of service (BOOS), or overfire air injection (OFA); low NO_x burners (LNB); flue gas recirculation (FGR); and reduced firing rate.

Two flue gas treatment (FGT) processes are receiving attention as a possible means of meeting stringent NO_x standards for utility boilers. Selective, noncatalytic reduction (SNR) of NO_x by ammonia injection has been developed and patented by Exxon Corporation. The process,[8] called Thermal De NO_x, has been commercialized for oil- and gas-fired boilers, and recent pilot-scale tests[9] confirm its effectiveness on coal-fired utility boilers. Disadvantages include possible ammonia emissions and a narrow temperature range of operation.

A second FGT process is known as selective catalytic reduction (SCR). In principle the process is similar to SNR, but the use of catalysts minimizes the temperature range restriction imposed by SNR. The process has been applied to commercial oil- and gas-fired boilers and is being tested on coal-fired boilers in Japan; it has not yet been installed on U.S. boilers.[10] The SCR process offers potential for use with combustion modifications when very high NO_x removal efficiencies are required.

The techniques proposed for fuel modification include fuel switching, fuel additives, and fuel denitrification.[4] These processes, however, do not currently appear attractive for NO_x control.

4.2 APPLICATION OF SELECTED NO_x CONTROL STRATEGIES

The four major utility boiler manufacturers - Babcock and Wilcox (B&W), Combustion Engineering (CE), Foster Wheeler (FW), and Riley Stoker (RS) - were asked to recommend methods of controlling NO_x emissions from their boilers. All four manufacturers recommend the use of low-NO_x burners. Only two, B&W and FW, have developed their own LNB's. Combustion Engineering has recently signed a contract with Mitsubishi Heavy Industries to use their LNB, although it has not yet been tested in the United States. Currently, Combustion Engineering uses overfire air (OFA) and believes that this technique controls NO_x well enough to meet New Source Performance Standards limits for NO_x emissions. This firm is also testing a new method called "offset air" which, if proven, can be used with OFA. Riley Stoker is testing an LNB design that should be commercially available within a few years. They will then discontinue using OFA because they believe that it causes an unacceptable drop in steam temperature.

Other methods of NO_x control that were commented upon by the boiler manufacturers are listed in Table 4-1. Being highly site-specific, the optimum NO_x control strategy depends on boiler type and age and on fuel properties. For new boilers, the vendors indicate that the present control scheme consists of applying one or more of the current NO_x control methods to a

TABLE 4-1. MANUFACTURERS' COMMENTS REGARDING NO_x CONTROL METHODS[11-15]

Combustion modification	
Low excess air (below design level)	Not recommended because it causes slagging and corrosion and increases unburnt carbon and CO; also it is not effective.
Water injection	Not recommended because it is not effective and causes a loss in boiler efficiency.
Flue gas recirculation	Not recommended because it is not effective; CE uses it with LNB's to prevent secondary air from entering the primary combustion zone.
Burners out of service	Not recommended because it causes either an increase of load on the other burners or a derate of boiler capacity; it is sometimes used to simulate OFA in tests.
Flue gas treatment	
Ammonia injection (SNR)	Not recommended because it is expensive, creates a risk of nitric acid formation, and reduces boiler efficiency.
Post combustion techniques (including SCR)	Not recommended because they are very expensive and present NO_x regulations can be met with other control methods.

boiler as it is being constructed. All of the vendors believe that present NO_x emission limitations can be achieved for new and existing boilers with present control technologies.[11-15]

Costs for retrofitting NO_x controls were estimated on a per-burner basis for B&W and FW boilers, and on a per-OFA-port basis for CE and RS boilers. B&W installed circular burners in boilers constructed before 1965 and after 1975. In the intervening decade, they installed cell burners (basically a group of two or three circular burners). All of the Foster Wheeler boilers incorporate circular burners.

The total cost of replacing a B&W or FW circular burner with an LNB was estimated to be $16,000. Babcock & Wilcox boilers with cell burners are much more difficult to retrofit with LNB's, requiring modifications of boiler tubes, windbox, and pressure parts. The estimated total direct cost for B&W boilers would be approximately $110,000 per burner. The estimated number of burners to be replaced with LNB's at each B&W and FW boiler is based on information from the vendors.[16,17]

Pending development of LNB's, overfire air is the currently recommended NO_x control strategy for CE and RS boilers. The total direct cost of an OFA port was estimated to be $80,000, and one OFA port is used over each column of burners. All CE boilers are tangentially fired and would use either four or eight OFA ports, depending on whether the furnace is split. Boilers with a capacity less than 600 MW were assumed to have four corners (furnace not split) and thus four columns of burners requiring four OFA ports. Larger boilers were assumed to be split, having eight corners and eight columns of burners requiring eight OFA ports. For RS boilers, the eight number of OFA ports was based on assumptions that the ports supply 20 percent of the total combustion air and that each port could supply approximately 43,000 cubic feet of air per minute.[18,19,20]

Certain boiler firing configurations and combustion modes are not amenable to NO_x reduction techniques. Cyclone boilers promote highly turbulent combustion and high flame temperature to achieve complete combustion and maintain the ash in a molten state for removal. Both of these conditions are very conducive to the formation of NO_x, and any attempt to minimize emissions could lead to a significant derating of boiler capacity and inhibit removal of slag (molten ash) from the boiler. Ash is also removed in molten form from a pulverized-coal-fired wet-bottom boiler, and attempts to reduce NO_x formation would yield results similar to those occurring in a cyclone boiler. Table 4-2 lists 52 boilers at 22 plants that are not amenable to NO_x control with LNB's or OFA ports.

Capital and annualized costs for 36 of the 50 highest NO_x emitters were based on the NO_x control strategy recommended by the boiler manufacturers and on the capital cost estimates discussed above. Of the 50 plants, 14 use boilers that cannot be retrofitted with NO_x controls. Appendix E gives detailed cost breakdowns for the 36 plants for which NO_x control costs were estimated.

TABLE 4-2. PLANTS AMONG THE 50 HIGHEST UNCONTROLLED NO_x EMITTERS FOR WHICH NO_x CONTROLS ARE NOT APPLICABLE

	Unit No.	Boiler type
Paradise	All	Cyclone
Powerton	All	Cyclone
New Madrid	All	Cyclone
Sioux	All	Cyclone
Coffeen	All	Cyclone
Kincaid	All	Cyclone
Kammer	All	Cyclone
Allen	All	Cyclone
Gannon	1-4 5, 6	Cyclone Wet-bottom
Michigan City	All	Cyclone
Thomas Hill	All	Cyclone
Big Bend	All	Wet-bottom
King	All	Cyclone
Bailly	All	Cyclone
Baldwin	1, 2	Cyclone
Muskingum River	3, 4	Cyclone
Conesville	1, 2	Cyclone
Joliet	5	Cyclone
Neal	1	Cyclone
St. Clair	5	Residual-oil-fired
Will County	1, 2	Cyclone
Karn	3, 4	Residual-oil-fired

The annualized costs consist of the annual incremental operating and maintenance cost and annual capital charges. The incremental operating and maintenance cost is the amount of increase in maintenance costs that is attributable to installation of additional equipment for NO_x control. Where OFA ports are recommended, this increment is assumed to be 1.5 percent of the capital cost. Where LNB's are recommended, it was assumed that no incremental operating and maintenance would be needed. The annual capital charges include taxes, insurance, general and administrative costs, and a capital recovery rate. Table 4-3 gives the estimated capital and annualized costs of implementing NO_x control strategies at the 36 plants for which control is feasible.

No cost estimates are given for such items as potential derating of the boiler, replacement power costs, or possible operational problems, chiefly because retrofit NO_x control costs are so highly variable. Actual capital costs can vary by a factor of 2, and equipment costs may represent only a small portion of the total retrofit cost. Cost data are sparse because few coal-fired boilers have been retrofitted with NO_x controls. The few available cost estimates vary greatly, largely because of the inflation of material and labor costs, geographical factors, boiler size and configuration, burner design, fuel characteristics, and other site-specific parameters.[22,23]

Installation of NO_x controls at the plants listed in Table 4-3 would reduce uncontrolled NO_x emissions from the 50 highest emitters from 2,444.69 x 10^3 tons to approximately 1,961.34 x 10^3 tons, a reduction of nearly 20 percent. It is not feasible to control NO_x at 14 of the plants, and at 8, only partial control is possible. Detailed breakdowns of the cost components at each plant are presented in Appendix D. The total capital cost of NO_x controls is estimated to be $298 million and the total annualized cost is estimated at $45.6 million per year.

TABLE 4-3. ESTIMATED COSTS OF INSTALLING NO_x CONTROLS AT 36 OF THE 50 HIGHEST UNCONTROLLED NO_x EMITTERS

Plant data			NO_x control costs				NO_x emissions		
Name	Capacity, MW	Capacity factor	Capital cost		Annualized cost		Uncontrolled, 10^3 tons	Controlled, 10^3 tons	NO_x reduction, %
			$ x 10^3	$/kW	$ x 10^3	mills/kWh			
Baldwin	634.5	0.67	1,041	1.64	166	0.04	141.91	130.83	8
Gavin	2600	0.71	31,480	12.11	4,564	0.28	73.96	44.38	40
Amos	2932.6	0.84	17,821	6.08	2,584	0.12	68.56	41.14	40
Muskingum River	1054.6	0.70	8,344	7.91	1,335	0.21	62.24	49.76	20
Clifty Creek	1303.56	0.75	2,496	1.91	427	0.05	58.93	35.36	40
Monroe	3279	0.63	38,632	11.78	5,600	0.31	58.35	35.01	40
Bowen	3160	0.58	4,164	1.32	666	0.04	53.95	40.46	25
Stuart	2440.8	0.64	28,616	11.72	4,148	0.30	53.42	32.05	40
Labadie	2220	0.59	2,080	0.94	333	0.03	49.93	37.45	25
Gibson	2672	0.52	3,332	1.25	476	0.04	47.66	28.60	40
Kyger Creek	1086.5	0.76	2,080	1.91	356	0.05	46.47	27.88	40
Cumberland	2600	0.48	31,480	12.11	4,564	0.42	43.81	26.29	40
Gaston	2012.8	0.71	2,861	1.42	463	0.04	43.39	28.78	34
Homer City	1850	0.80	2,705	1.46	394	0.03	42.81	25.68	40
Conesville	1711	0.44	2,601	1.52	458	0.07	42.01	34.97	17
Belews Creek	2160	0.62	25,756	11.92	3,708	0.32	41.67	25.00	40
Cardinal	1880.46	0.71	16,169	8.60	2,361	0.20	41.48	24.89	40
Wansley	1730	0.73	2,082	1.20	327	0.03	40.98	30.74	25
Sherburne	1440	0.54	2,082	1.45	329	0.05	39.63	29.72	25
Marshall	2000	0.65	3,122	1.56	507	0.04	37.56	28.17	25
Keystone	1872	0.66	2,082	1.11	339	0.03	37.53	28.15	25
Joliet	1320	0.76	2,080	1.58	343	0.04	37.50	30.65	18

(continued)

TABLE 4-3 (continued)

Plant data			NO_x control costs				NO_x emissions		
Name	Capacity, MW	Capacity factor	Capital cost		Annualized cost		Uncontrolled, 10^3 tons	Controlled, 10^3 tons	NO_x reduction, %
			$ x 10^3	$/kW	$ x 10^3	mills/kWh			
Neal	1445.2	0.52	1,977	1.37	284	0.04	36.19	25.05	31
Kingston	1723	0.65	4,680	2.72	885	0.09	35.87	26.90	25
Sammis	2303.5	0.49	16,422	7.13	3,527	0.36	35.71	21.42	40
Montour	1534	0.78	2,082	1.36	333	0.03	35.47	26.60	25
St. Clair	1547	0.24	2,184	1.41	374	0.12	34.41	24.55	29
Hatfield	1728	0.65	21,462	12.42	3,135	0.32	34.39	20.63	40
Brunner Island	1558	0.75	2,081	1.34	341	0.03	34.16	25.62	25
Will County	897	0.51	1,040	1.16	178	0.04	33.97	29.48	13
Columbia	1024	0.58	1,040	1.02	164	0.03	33.90	25.43	25
Roxboro	1813.05	0.63	4,163	2.30	674	0.07	33.48	25.11	25
Widows Creek	1980	0.46	2,600	1.31	453	0.06	31.95	21.81	32
Mansfield	1670	0.53	2,186	1.31	312	0.04	31.01	18.61	40
Mitchell	1632.3	0.67	2,082	1.28	304	0.03	30.46	18.27	40
Karn	530	0.74	938	1.86	164	0.05	29.17	25.10	14

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13. Telephone conversation. S. Sabatini, PEDCo Environmental, Inc., with H. J. Melosh, Foster Wheeler, December 3, 1980.

14. Telephone conversation. S. Sabatini, PEDCo Environmental, Inc., with E. Campobennedetto, Babcock and Wilcox, December 4, 1980.

15. Telephone conversation. S. Sabatini, PEDCo Environmental, Inc., with A. H. Rawdon, Riley Stoker, December 4, 1980.

16. Telephone conversation. S. Sabatini, PEDCo Environmental, Inc., with D. Lowery, Babcock and Wilcox, December 17, 1980.

17. Telephone conversation. S. Sabatini, PEDCo Environmental, Inc., with H. J. Melosh, Foster Wheeler, December 17, 1980.

18. Telephone conversation. G. Baker, PEDCo Environmental, Inc., with M. McCartney, Combustion Engineering, December 15, 1980.

19. U.S. EPA. Proposed Guidelines for Determining Best Available Retrofit Technology for Coal-Fired Power Plants and Other Major Stationary Sources. EPA-450/3-80-009a. July 1980.

20. Telephone conversation. S. Sabatini, PEDCo Environmental, Inc., with A. H. Rawdon, Riley Stoker, December 19, 1980.

21. Meeting notes. K. Hsiao, Pullman Kellogg with A. H. Rawdon, Riley Stoker, Worcester, Massachusetts. March 20, 1979.

22. Stearns-Roger Engineering Corporation. Review of EPA Document "Retrofit Guideline for Coal-Fired Power Plants" by Pullman Kellogg. EPA Contract No. 68-02-2619. September 1979.

23. KVB. NO_x Best Available Retrofit Technology Implementation Considerations for Coal-Fired Power Plants. Report No. KVB2-28610-938/R. August 1980.

Q5. Are there any waste management problems associated with the installation of scrubbers on fossil fuel fired plants? If so, what are they? Is groundwater affected, and if so, how?

A. There are three considerations which should be addressed in this area. First, is scrubber waste hazardous? Our preliminary conclusion is that the scrubber waste stream is not hazardous. The Department of Energy (DOE) is currently conducting a waste characterization study which examines all waste streams from coal fired utility plants.1/ We will be making this study available to the Environmental Protection Agency (EPA) in the future. The general conclusion is that, while the waste stream volume will considerably increase as more utilities become coal-based, the waste streams themselves are not hazardous. This includes scrubber waste streams.

Second, how effective are scrubber waste management techniques? The consideration of potential leaching into groundwater raises the question of management of the scrubber waste stream. A draft study which the EPA has prepared 2/ and another study by the Electric Power Research Institute have found that the management practices which are used to contain these waste streams are very effective and do not result in contamination of groundwater to any significant extent. That is, while in some cases some effect upon groundwater has been found, the level of impact has been well below current pollution standards. A more important question concerns the extent to which these management practices will be continued as generated scrubber wastes increase in volume over time. If the conclusion that scrubber wastes are not hazardous is maintained, then these wastes will not be regulated under

Subtitle C (as hazardous wastes) of the Resource Conservation and Recovery Act (RCRA); however, we would expect these wastes to be regulated under Subtitle D (solid wastes) of RCRA. Consequently, the present management techniques to control these waste streams will continue or be improved through a regulatory framework primarily managed by states.

A third problem and a very significant one, concerning the application of scrubbers on fossil fuel fired plants will be the requirement to handle the large volume of scrubber waste which will steadily increase over time and the cost of managing these waste streams. In the utility sector, the DOE estimate is that scrubber sludge alone will increase from approximately 8 million tons in 1985 to approximately 48 million tons in the year 2000.3/ This increase in sludge generated is primarily associated with the requirement to meet the 1979 New Source Performance Standards. The cost for managing the scrubber waste streams can vary considerably, based on volume of waste generated, type of waste, type of disposal or management method, size of plant, etc. EPA estimates range from $15 to $53 per dry metric ton of FGD waste for handling, processing, transport, and disposal (1982 dollars).4/

References to Q.5

1. Utility Waste Stream Characterization Study being conducted by the Assistant Secretary for Fossil Energy, DOE.

2. "Full-Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants," Draft Report, U.S. EPA, December 1983.

3. Environmental Trends Analysis for the Fourth National Energy Plan (as of yet, unpublished), U.S. Dept. of Energy.

4. See Reference 2.

Q6. Where are we now in terms of achievable technology with regard to technology on scrubber options and new developing technologies. How do the costs of new technologies compare with present scrubber technology and when might these newer, cost efficient technologies be available for the marketplace?

A. There are a number of ways to reduce the emission of acid rain precursors. The attached table lists a number of the alternatives, the potential emission reductions, the annual incremental control costs, and our projection of the commercial availability for those which are not now commercially available.

POTENTIAL PERFORMANCE OF ACID RAIN CONTROL TECHNOLOGIES

TECHNOLOGY	EMISSIONS REDUCTION (%)		INCREMENTAL COST (MILLS/KWHr)	$/TON SO2	MATURITY
	SOx	NOx			
LIMESTONE SCRUBBER	90-95	NEG.	13-20	600-950	AVAILABLE
DRY SCRUBBER	70	NEG.	10-12	780-1080	AVAILABLE
LIMESTONE INJECTED[1] MODIFIED BURNER	30-60	40-50	1-9	215-1390	COMMERCIAL EARLY 90s
ADVANCED SOx/NOx CLEANUP DEVICES	90-95	90-95	6-10	270-610	COMMERCIAL EARLY 90s
CONVENTIONAL PHYSICAL COAL CLEANING	33-50	NEG.	2-5	250-720	AVAILABLE
ADVANCED PHYSICAL COAL CLEANING	55-65	NEG.	4-7	270-450	COMMERCIAL LATE 80s
PHYSICAL AND CHEMICAL COAL CLEANING	80-94	NEG.	13-20	600-950	COMMERCIAL EARLY 90s
PRESSURIZED FLUIDIZED BED COMBUSTION RETROFIT	90-98	75-85	10[2]	420-460	COMMERCIAL MID 90s
ATMOSPHERIC FLUIDIZED BED COMBUSTION RETROFIT	90-95	50-75	12	520-560	COMMERCIAL EARLY 90s

1. EPA FUNDED

2. DOES NOT INCLUDE THE BENEFITS OF LOWER COST ADDITIONAL CAPACITY.

Q.7 What is the remaining lifetime on the largest emitters of sulfur dioxide? (Answer this in terms of the 50 largest emitters in the nation)

A. There is no accepted method to predict when existing power plants are likely to retire. Therefore we have addressed this question by providing a list of the year each unit in the 50 largest sulfur dioxide power plant emission sources came on line. Table 1 provides a summary in 5 year increments of these units.

Table 1

Units' Age in Top-50 Power Plant SO2 Emission Sources

(Coal-Fired Units Only)

Initially On Line	Present Age (Years)	Number of Units
1926-1930	54-58	1
1931-1940	--	0
1941-1945	39-43	2
1946-1950	34-38	11
1951-1955	29-33	47
1956-1960	24-28	33
1961-1965	19-23	17
1966-1970	14-18	30
1971-1975	9-13	32
1976-1980	4-8	14
Total		187

The median aged unit is in the range of 24 to 28 years, having begun operation on or before 1960. The greatest number of units initiating operation in any of the 5-year increments was 47 of the 187 coal-fired units (25%), beginning operation from 1951 to 1955.

The lowest emitter of this set of power plants emitted 56 thousand tons of sulfur dioxide in 1980. Seven U.S. copper smelting facilities were estimated to emit more annual SO2 emissions in 1980, than this plant, according to statistics developed for the U.S.-Canada Memorandum of Intent on Transboundary Air Pollution. These smelters are listed in the following table with their first year of operation and their location. All of the smelters are located in western states.

Table 2

Largest Sulfur Emitting Smelters in 1980

Plant	1980 SO2 Emissions (Tons)	First Year of Operation
Asarco, Arizona	107,000	1912
Asarco, Washington	102,000	1890
Kennecott, Arizona*	65,000	1958
Kennecott, Nevada*	86,000	1908
Magma, Arizona	104,000	1955
Phelps Dodge Douglas, Arizona	258,000	1904
Phelps Dodge Morenci, Arizona	102,000	1942

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* operations suspended at present

Largest Power Plant SO2 Emitters in 1980
in 31 State Eastern Area

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
Alabama (1)	TVA	Colbert	1	1955		
			2	1955		
			3	1955		
			4	1955		
			5	1965		
					122.4	29
Florida (3)	Fla. Power	Crystal River	1	1969		
			2	1977		
					67.2	47
	Gulf Power	Crist	1	1945*		
			2	1949*		
			3	1952*		
			4	1959		
			5	1961		
			6	1970		
			7	1973		
					74.7	42
	Tampa Elec.	Big Bend	1	1970		
			2	1973		
			3	1976		
					137.9	25
Georgia (2)	Ga. Power	Wansley	1	1976		
			2	1978		
					207.5	13

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* non-coal fired unit

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
(con.) Georgia	Ga. Power	Yates	1	1950		
			2	1950		
			3	1952		
			4	1957		
			5	1958		
			6	1974		
			7	1974		
					99.3	33
Illinois (4)	Central Ill.	Coffeen	1	1965		
			2	1972		
					156.5	22
	Commonwealth Edison	Kincaid	1	1967		
			2	1968		
					209.3	11
	Electric Energy	Joppa	1	1953		
			2	1953		
			3	1954		
			4	1954		
			5	1955		
			6	1955		
					98.1	34
	Ill. Power	Baldwin	1	1970		
			2	1973		
			3	1975		
					258.3	8

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
Indiana (7)	Ind. & Mich.	Breed	1	1960	70.1	45
		Tanners Creek	1	1951	90.2	37
			2	1952		
			3	1954		
			4	1964		
	Ind. Ky.	Clifty Creek	1	1955	295.0	5
			2	1955		
			3	1955		
			4	1955		
			5	1955		
			6	1956		
	No. Ind. PS	Mich. City	1	1930	85.1	39
			2	1950		
			3	1951		
			12	1974		
	Pub. Ser. of Ind.	Cayuga	1	1970	113.2	31
			2	1972		
		Gibson	1	1976	307.5	4
			2	1975		
			3	1978		
			4	1979		
		Wabash River	1	1953	63.8	48
			2	1953		
			3	1954		
			4	1955		
			5	1956		
			6	1968		

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
Kentucky (4)	Big Rivers Elec.	Coleman	1	1969		
			2	1970		
			3	1971		
					68.5	46
	Ky. Util.	Ghent	1	1974		
			2	1977		
					88.0	38
	Louisville G&E	Mill Creek	1	1972		
			2	1974		
			3	1978		
					56.1	50
	TVA	Paradise	1	1963		
			2	1963		
			3	1970		
					363.9	2
Missouri (5)	Assoc. Elec. Co.	Hill	1	1966		
			2	1969		
					135.8	26
		New Madrid	1	1972		
			2	1977		
					212.5	10
	Kansas City P&L	Montrose	1	1958		
			2	1960		
			3	1964		
					161.6	21
	Union Elec.	Labadie	1	1970		
			2	1971		
			3	1972		
			4	1973		
					268.6	7
		Sioux	1	1967		
			2	1968		
					110.7	32

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
Mississippi (1)	Miss. Power	Watson	1	1957*		
			2	1960*		
			3	1962*		
			4	1968		
			5	1973		
					62.2	49
Ohio (9)	Cardinal Uper.	Cardinal	1	1967		
			2	1968		
			3	1977		
					123.0	28
	Cleveland El.	Ashtabula	1	1930*		
			2	1930*		
			3	1930*		
			4	1930*		
			5	1958		
			6	1948		
			7	1948		
			8	1948		
			9	1948		
					79.0	41
		Avon Lake	1	1926*		
			2	1926*		
			3	1928*		
			4	1929*		
			5	1943		
			6	1949		
			7	1949		
			8	1959		
			9	1970		
					92.9	35

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* non-coal fired units

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
Ohio (con.)		East Lake	1	1953		
			2	1953		
			3	1954		
			4	1956		
			5	1972		
					169.1	19
	Columbus & South	Conesville	1	1959		
			2	1957		
			3	1962		
			4	1973		
			5	1976		
			6	1978		
					171.6	18
	Ohio Edison	Burger	1	1944		
			2	1947		
			3	1950		
			4	1955		
			5	1955		
					82.3	40
	Ohio Power	Gavin	1	1974		
			2	1975		
					402.1	1
		Muskingum	1	1953		
			2	1954		
			3	1957		
			4	1958		
			5	1968		
					273.2	6
	Ohio Valley Electric	Kyger Creek	1	1955		
			2	1955		
			3	1955		
			4	1955		
			5	1955		
					201.8	14

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
Pennsylvania (4)	Penn Elec.	Conemaugh	1	1970	191.6	15
			2	1971		
		Homer City	1	1969	180.3	17
			2	1969		
			3	1977		
	Penn P&L	Brunner Island	1	1961	138.9	24
			2	1965		
			3	1969		
	West Penn Power	Hatsfield Ferry	1	1969	164.7	20
			2	1970		
			3	1971		
Tennessce (5)	TVA	Allen	1	1958	73.5	43
			2	1959		
			3	1959		
		Cumberland	1	1973	325.8	3
			2	1973		
		Gallatin	1	1956	124.5	27
			2	1957		
			3	1959		
			4	1959		

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
(con.) Tennessee		Johnsville	1	1951		
			2	1951		
			3	1952		
			4	1952		
			5	1952		
			6	1953		
			7	1958		
			8	1959		
			9	1959		
			10	1959		
					184.2	16
		Sevier	1	1955		
			2	1955		
			3	1956		
			4	1957		
					71.4	44
West Virginia (4)	APS:Monong. Power Co.	Fort Martin	1	1967		
			2	1968		
					92.9	35
		Harrison	1	1972		
			2	1973		
			3	1974		
					216.1	9
	AEP:Ohio Power Co.	Kammer	1	1958		
			2	1958		
			3	1959		
					148.0	23
		Mitchell	1	1971		
			2	1971		
					207.7	12

State	Company	Power Plant	Unit No.	Yr. First on Line	1980 Emissions (thousand tons)	"Top-50" Rank
Wisconsin (1)	Wis. Elec. Power	South Oak Creek	1	1953		
			2	1954		
			3	1955		
			4	1957		
			5	1959		
			6	1961		
			7	1965		
			8	1967		
					120.3	30

Q8. What are the sulfur dioxide emission densities in the West as compared to those in the East? How much of the coal fired generation in the West is scrubbed?

A. Table 1 provides a display of sulfur dioxide emission densities by Federal Region for 1980 emissions as compiled in the draft report "Historic Emissions of Sulfur and Nitrogen Oxides in the United States From 1900 to 1980" by G. Gschwandtner, et al., October 5, 1983, for the Environmental Protection Agency. For the five regions east of the Mississippi River, the emissions densities average 20.7 tons per square mile and range from 9.3 tons/square mile to 31.6 tons/square mile. For the western regions in the contiguous states, the average in 1980 was 2.9 tons per square mile, ranging from 1.1 tons/square mile to 6.7 tons/square mile. The national average (for 48 states) was 8.4 tons per square mile.

Because much of the acid rain discussion centers on the 31 states east of or adjacent to the Mississippi, Table 1 also provides this summary plus the average for the complimentary 17 western states. The eastern states average emissions density is 18.4 tons SO2 per square mile, while the western states average is 2.2 tons/square mile. Thus the ratio of eastern states emission density to the western states is over eight times.

Based on data compiled by Argonne National Laboratories, there were, in September 1983, 115 units that had operational scrubbers. Sixty-four of these units were in Regions 1-5 (eastern states), while 51 units were in Regions 6-10 (western states). The 51 western plants have an aggregated capacity of 21, 157 MW, while the capacity of the 64 eastern plants is 19,809 MW.

Table 1

United States Sulfur Dioxide Emissions Densities

(tons/sq. mile) in 1980

	Area (x10(3) mi(2))	1980 SO2 Emissions (x10(3) tons)	Ratio SO2/Area
Region 1	62.9	588	9.3
2	55.3	1207	21.8
3	120.8	3822	31.6
4	370.2	5693	15.4
5	323.4	7966	24.6
Total	932.6	19300	20.7
Region 6	549.1	1553	2.8
7	283.2	1888	6.7
8	574.0	953	1.7
9	379.7	1202	3.2
10	245.5	271	1.1
Total	2031.5	5870	2.9
48 state Total	2964.	25200	8.4
31 eastern states	1154.	21200	18.4
17 western states	1810.	3950	2.2

APPENDIX B — REGION MAPS

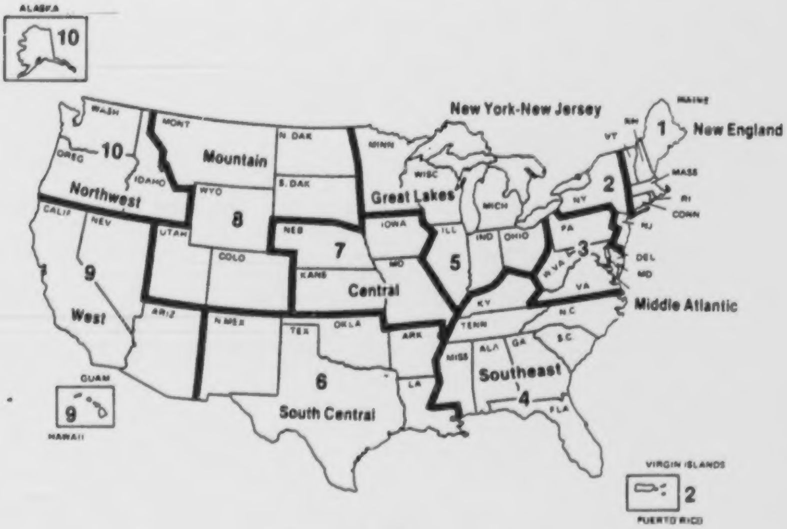

ALASKA
10
New York-New Jersey
MAINE
1
New England
WASH
MONT
N DAK
MINN
VT
NH
OREG
10
Mountain
WISC
2
MASS
IDAHO
S. DAK
Great Lakes
MICH
NY
RI
Northwest
WYO
CONN
CALIF
NEV
8
NEB
IOWA
ILL
PA
NJ
UTAH
7
IND
OHIO
3
9
COLO
KANS
MO
5
W VA
DEL
MD
Central
VA
West
KY
N C
Middle Atlantic
ARIZ
N MEX
OKLA
TENN
TEX
ARK
S C
MISS
ALA
GA
6
Southeast
GUAM
LA
4
9
South Central
FLA
HAWAII
VIRGIN ISLANDS
2
PUERTO RICO

Figure B-1
Federal Regions

Q9. What is the average sulfur content of the coal burned in the East as compared to that in the West?

A. Electric utilities used 85 percent of the coal consumed in the United States in 1983. The sulfur content of coal delivered to electric utilities east of the Mississippi River averaged 1.9 percent. Coal delivered to utilities west of the Mississippi averaged 0.8 percent sulfur. The average for the contiguous 48 states was 1.47 percent.

Taking the varying heating values into account, coal delivered to eastern utilities would produce an average SO_2 emission of 3.29 pounds per million Btu's, as burned. Coal delivered to western utilities would produce an average of 1.86 pounds of SO_2 per million Btu's, as burned. For the total U.S., the average was 2.80 pounds of SO_2 per million Btu's, as burned.

Q10. How much in dollar terms is spent on environmental controls at a new plant? Are there any dollar averages for retrofitting an existing plant?

A. In a new power plant, the scrubber will commonly cost $140-175/kw (1982 dollars). This includes costs associated with the construction of disposal ponds or landfills. The cost for all pollution control equipment including FGD, particulates control, NOx control and water treatment has been estimated by EPRI (K. Yeager's 9/20/83 testimony to House Committee on Science and Technology) to be approximately 40 percent of the capital cost of a new plant. The average cost to retrofit large plants with lime/limestone FGD systems is in the range of $190/kw to $245/kw (1982 dollars) according to analyses sponsored by the Electric Power Research Institute.

Q11. What would the total costs of S. 768, H.R. 3400, and H.R. 4404 be? What if any benefits would there be from these expenditures? Could these costs be translated into dollars per pounds of fish saved in the Adirondacks?

A. As shown in the attached Table A-1, there have been a number of studies attempting to estimate total costs of various SO2 emissions reduction levels. The estimates vary with the amount of SO2 emission reduction, the constraints on how the reductions may be achieved, and the assumptions concerning the growth in fuel demand.

As an illustration of how control program constraints can affect annual cost estimates, compare estimates 27 and 39. Both assume 10 MTY SO2 rollback, but estimate 27 assumes that emissions can be traded throughout the 31 eastern states to effect a least-cost solution, while estimate 39 assumes that the top 50 SO2 emitters must either apply NSPS level controls (high efficiency scrubbers) or retire (and replace) older units as a major component of the 10 MTY reduction. Since scrubbing or retirement/replacement are more costly than low sulfur coal use (the method of choice for most plants under a least-cost strategy), estimates 27 and 39 differ by over $4 billion per year.

DOE staff tend to anticipate the higher estimates within the range are the more likely values because practical realities (such as state restrictions on emission trading across state lines and capital aversion by utilities) inhibit truely least-cost economic behavior.

Another point worthy of note is that emission reductions may or may not include the requirement to offset emissions growth. Estimates 29, 32, 33 and 38 all assume that offsets will be required. They also assume growth in emissions between 1980 and 1995 which must be offset. Thus, a nominal 8-12 MTY rollback relative to 1980 becomes a 9.8-14.2 MTY rollback relative to 1995, depending on growth assumptions. Generally, the House proposals would not require offsets while the Senate proposal (S. 768) would require offsets.

The year 1995 represents the peak annualized cost for rollback schemes which must be completed by 1995. The shape of an annual cost curve over time is illustrated in Figure A-1. The case (estimate 36) requires 8 MTY nominal SO2 rollback by 1995. Growth between 1980 and 1995 must be offset, but growth after 1995 need not be offset in this case. Thus the reduction of SO2 in 1995 is 9.2 MTY but the emissions curve rises after 1995. If the increase in emissions after 1995 had to be offset, then the cost curve would not fall as rapidly.

The sharply concave shape of the cost curves bounding the scatter in Figure A-1 results from the depletion of lower cost control opportunities as the amount of SO2 reduction increases and illustrates how costs accelerate at the higher SO2 emission reduction levels.

The range of 1995 annual costs for a nominal 10-12 MTY SO2 rollback runs from a low estimate of $2.7 billion per year (lower curve, 10 MTY rollback, no growth offset) to a high estimate of well over $10 billion per year (upper curve, 12 MTY nominal rollback with some growth requiring offsets).

We know of no generally accepted studies or methodologies which have been able to address the second and third parts of this question relating to quantification of benefits.

TABLE A-1

ESTIMATES OF COSTS OF SO_2 ROLLBACK IN 1995

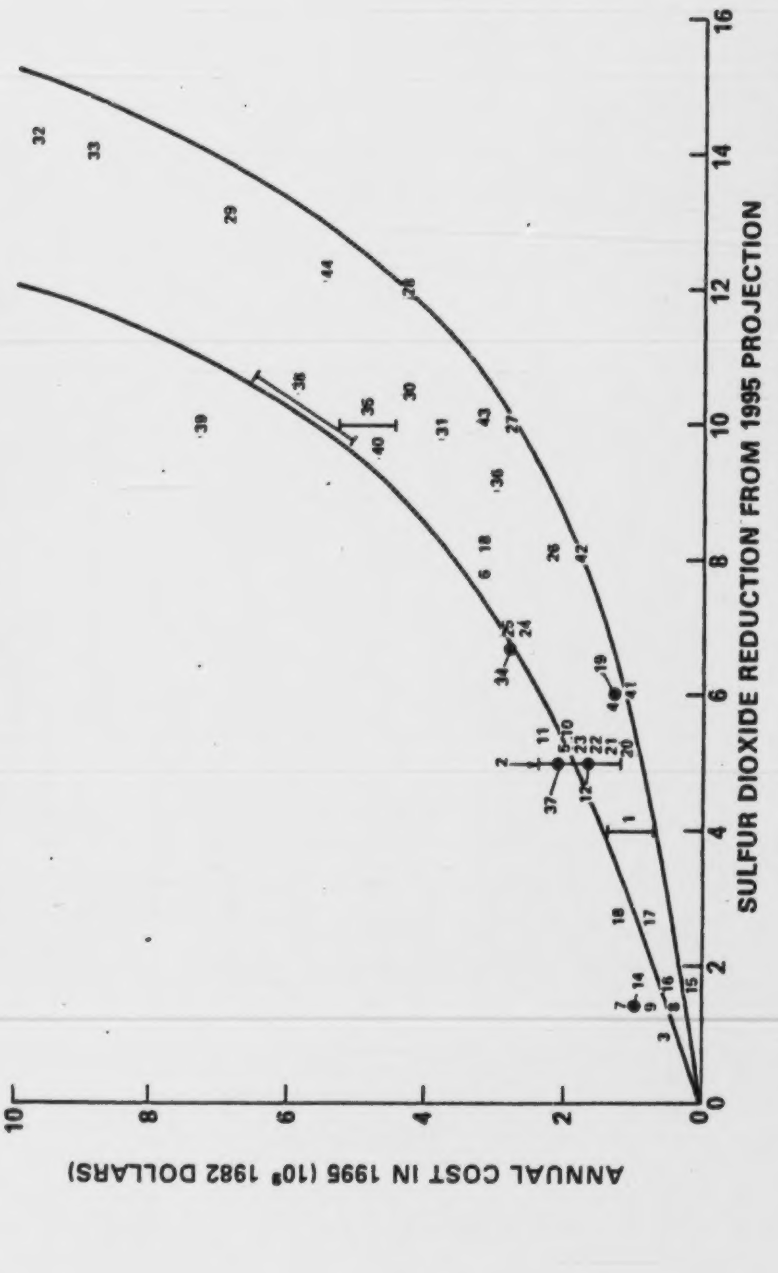
No.	CONTRACTOR CUSTOMER	STRATEGY	SO_2 1995 (10^6 TPY)	ANNUAL COST 1995 (10^9 1982 $)	CUMULATE CAPITAL (10^9 1982 $)	SCRUBBED CAPACITY (GW)	HIGH SULFUR COAL AFFECTED(MTY)
1	DOE 1982	SWITCH	4	0.7 - 1.4	-	-	67
2		FGD	5	1.2 - 2.4	-	39	-
3		CLEAN	1	0.4 - 0.5	-	-	-
4	PEDCO/ DOE 1981	SWITCH	5.9	1.3	-	-	176
5		FGD 60%	5.2	2.0	-	80	-
6		FGD 90%	7.8	3.2	-	80	-
7		CLEAN	1.5	1.0	-	-	-
8	TEKNE-KRON/ EPA/DOE 1981	4lb CAP	1.5	0.4	-	3	16
9		4lb CAP & LCP	1.5	0.7	-	22	10
10		2lb CAP	5.5	2.0	-	41	52
11		2lb CAP & LCP	5.4	2.3	-	55	19
12		30% FGD	5.0	1.7	-	43	14
13		50% FGD	8.2	3.2	-	86	11
14		CLEAN	1.4	0.9	-	-5	16
15	ICF/ EPA/DOE 1981	10% Regional	1.7	0.1	1.1	0	18
16		10% Each State	1.7	0.5	1.6	0.6	21
17		4lb CAP & LCP	2.7	0.8	1.7	12	20
18		4lb CAP & LCP	2.7	1.2	2.5	13	17
19		15¢/lb	6.0	1.3	4.3	7	62
20		30% Regional	5.1	1.1	4.4	7	46
21		30% Regional & LCP	5.1	1.4	6.1	9	32
22		30% Each State	5.1	1.7	10.0	9	45
23		30% Each State & LCP	5.1	1.8	11.4	12	35
24		2lb CAP	7.0	2.6	12.0	26	67
25		2lb CAP & LCP	7.0	2.8	12.8	31	46
26	ICF/OTA'82	LC, - 2:1 NO_x	8.1	2.2	6.2	-	53
27	ICF/NWF '83	Least Cost	10	2.8	14.7	-	37
28	ICF/EEI 1983	LC, - 2:1 NO_x	12	4.3	16	-	34
29		LC - IT	13.1	6.9	26	-	31
30	ICF/EPA 1982-3	LC - IT	10.5	4.3	6	19	79
31		LC	10	3.8	3	8	86
32		LC - OS	14.2	9.7	32	116	65
33		LC - OS - IT	14.0	8.8	30	106	58
34		LCP	6.7	2.8	16	50	0 (+68)
35		LCP	10.2	4.9	25	80	0 (+53)
36		"SENATE" I	9.2	3.0	3	9	45
37		12 STATE	5.0	2.1	3	14	7
38		"SENATE" II - OS	9.8-10.8	5.1-6.5	3-8	9-25	45-72
39	TBS/EEI	HR 3400	10	7.3	25	47-68	-
40	FECHAN/ OTA	HR 3400	10	4.5-5.3	-	-	22-56
41	ICF/ACE 1984	6 LC	6.2	1.1	1.2	0	58
42		8 LC	8.1	1.8	1.8	0	85
43		10 LC	10.1	3.2	3.7	5	119
44		12 LC	12.2	5.5	11.3	33	125

ABBREVIATIONS:

SWITCH - Low S coal only
FGD - Retrofit scrubbing only
CLEAN - Coal washing only
CAP - Emission rate limit each plant (eg 4lb $SO_2/10^6$ BTU)
LCP - Local coal protection
LC - Least cost
2:1 NO_x - Half credit for SO_2 if NO_x reduced
IT - Emission trading limited to intrastate

FIGURE A-1

ESTIMATES OF 1995 ANNUAL COSTS OF SO_2 ROLLBACK



*SEE TABLE A-1 FOR STUDY REFERENCES

Q12. Is there any relationship between net imports of power from Canada as an alternative to retrofitting scrubbers on American utilities if acid rain controls are imposed at this time? Do long-term bulk power imports from Canada constitute an attractive alternative to coal fired generators for capacity additions in the late 1980's and 1990's, despite coal's continuing economic advantage?

- o Would electric rates be any higher under imported power than if coal based?
- o How much power is Canada importing into this country? How much of an increase is this from 1981?
- o Is it possible that increased purchases of power from Canada might displace the construction of new U.S. generating capacity?

Q13. How might an acid rain control program as envisoned by S. 768 or H.R. 3400 result in this nation's increased dependence on imported power from Canada? What would this reliance mean in terms of our policy of energy independence? In terms of lost domestic energy capacity?

A. Any increase in U.S. electricity prices or shortfall in available U.S. or regional power capacity would enhance the possibility that this nation would import more power from Canada. The emission rollback bills before Congress would certainly increase the cost of generating electricity, making our power more expensive relative to Canadian power. In addition, the bills would increase the possibility of capacity insufficiency as well, because of derating and increased early retirements of older plants. Thus, it appears that emission rollback measures could well result in additional imports of electricity.

This subject is also addressed in a 1983 DOE report 1/ and a 1983 Canadian Energy Research Institute (CERI) report.2/ The CERI report states that the potential for future electricity import growth from Canada is up to a 20-fold increase over current levels. This is a

Canadian view, not necessarily endorsed by DOE. DOE expects that electricity imports would roughly double between 1982 and 1990 in the absence of any other stimulating factors, such as more expensive domestic electricity costs. No DOE estimates post-1990 have been made. For reference to current import levels, following are net imports of electricity from Canada for the last 3 years:

1981	33,500,000 MW-hr
1982	30,700,000 MW-hr
1983	35,258,000 MW-hr

Currently, the primary factor governing the importation of electric power is economics.3/ Generally, U.S. utilities are purchasing imported power from hydroelectric and low-cost, coal-fired plants. Many long-term bulk power contracts are costed at 80% of the prevailing domestic regional cost of producing electricity from fossil fuels. If the bulk of regional electricity were coal-based, imported electric rates would not be higher than the primarily coal-based rates. However, in the Northeast, which accounts for more than half of this country's imported electricity, 4/ imported rates may be considerably higher than coal-fired rates, since oil, the prevailing fossil generation source, is substantially more expensive than coal.

Finally, it is certainly conceivable that increased purchase of Canadian-generated electricity could displace the construction of new U.S. plants, if the contracts for such imports are firm.

Canada's economic interest in increasing electricity exports to the United States is very clear. Accordingly, the economic and national security implications of any policy or legislation that would tend to increase such exports deserves the most careful scrutiny.5/

References Q.12-13

1. "The Future of Electric Power in America: Economic Supply for Economic Growth," DOE/PE-0045, June 1983, pp. 4-20.

2. "Potential Benefits and Costs of Canadian Electricity Exports," Canadian Energy Research Institute, Report No. 83-1, April 1983.

3. "Electricity Exchange Across International Borders-1982," DOE/RG-0062, May 1983, p. 4.

4. Ibid, Table 2.

5. "The Silent Alliance"; James M. Friedman, Michael S. McMahan; Regency-Gateway, 1984; p. 43.

Q14. The Ad Hoc Committee to Review the National Acid Precipitation Assessment Program (NAPAP) filed its report in December 1983. The report included this recommendation at page 12:

> "The Federal funding level for development and demonstration of new control technology should be increased substantially to complement on-going industry commitments. The development of new and improved, retrofittable, emission control technologies followed by successful pilot- and demonstration-scale testing, is of key importance in the potential long-term mitigation of acid deposition."

What was the reaction of the OMB and the Administration in general to this recommendation?

A. The Administration recognizes that direct combustion will still be the dominant use of coal well into the foreseeable future. This means that the nation must continue to address the fundamental obstacles to coal burning, specifically those associated with the environmental acceptability of coal.

This recognition is reflected in the Department's proposed 1985 budget for the Office of Fossil Energy. The theme of environmental compliance runs throughout the budget request. Although essentially all of the technological concepts being pursued offer the potential for improved environmental performance, those programs that have a direct bearing on reducing acid rain precursors, specifically sulfur dioxide (SO_x), nitrogen oxides (NO_x), and particulates, are focused on critical points in the coal "fuel chain": precombustion, during combustion, and post-combustion. In addition, there is a program devoted to cleaning gases produced as a result of coal gasification.

These programs account for more than $57 million of our coal budget, or about one-third of it. The comparable funding level of FY 1984 was just under $37 million. The $20 million increase we are proposing is a significant component of the President's commitment, expressed in his State of the Union Address, to increase acid rain related efforts.

We do not believe that additional funding would result in any further progress in the development of technologies to mitigate acid rain precursor technologies. The FY 1985 Fossil Energy budget request is sufficient to ensure that a sound base of technical data is created to permit the private sector to decide which of the various advanced control options make the most commercial sense. With regard to engineering development, we believe that, based on Federal efforts in basic technological development and proof-of-concept testing on a small scale, the private sector is better suited to decide which processes to carry to a large scale and that such systems can best be selected and financed by the private sector. By having industry apply its own selection criteria, not biased by the availability of Federal funds for specific projects, the best decisions will be made. Most of the private sector effort in the demonstration of new technologies is being funded and managed by the Electric Power Research Institute (EPRI). Over the next five years, EPRI plans to spend approximately $200 million for the RD&D on these technologies.

APPENDIX E

Answers to Questions Submitted to The Honorable A. Alan Hill, Chairman, Council on Environmental Quality

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Richard

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL ON ENVIRONMENTAL QUALITY
722 JACKSON PLACE, N. W.
WASHINGTON, D. C. 20006

24 May 1984

Official Committee File

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
MAY 29 1984
WASHINGTON, D.C. 20510

The Honorable James A. McClure
Chairman
Committee on Energy and Natural Resources
United States Senate
Washington, DC 20510

Dear Chairman McClure:

The attached is in response to the question submitted by Senator Ford with regard to my testimony on April 30, 1984 at the oversight hearing on the implementation of the Acid Precipitation Act of 1980.

I appreciate the opportunity to testify on this very important issue. Please contact me if I can supply any additional information.

Sincerely,

A. Alan Hill

A. Alan Hill
Chairman

Question submitted by Senator Ford:
Mr. Hill, your August 19, 1982, testimony before this Committee contains the following statement:

"Although, acid rain is blamed for a variety of ills, actual causes and effects of the phenomenon are not fully understood. In my view we must address three questions before we can begin to consider an emissions control strategy in legislation. First, we must ask how well we understand atmospheric chemistry and the long-range transport, ultimate deposition, and ecological effects of acid rain. Second, we must determine whether there is a relationship between natural and manmade influences on the development of acid rain. Finally, we must determine how particular strategies to control emissions will affect the amount of acid rain generated and its effects on the ecosystem. At this time we cannot answer any of these questions satisfactorily.

Mr. Hill, can we answer any, or all, of these questions satisfactorily at this time?"

Mr. Hill: Senator Ford, I am grateful for the opportunity to elaborate on my testimony. Let me step back for a minute and reflect on the August 1982 hearings that you mentioned in your question. As you know, there was a great deal of concern that acid rain was not being properly addressed. Let me assure you and the Committee that the Reagan Administration is doing everything possible to address these important questions. Our understanding is evolving and many of the critical gaps in our knowledge of acid rain are being filled in.

Now to the specifics of your question. With respect to question 1, I must admit that we cannot at this time speak with assurance concerning the atmospheric chemistry, transport, deposition, and the effects of acid rain. Consequently, question 3 involving the comparative evaluation of the effect of specific control strategies is not possible. However, with respect to your concerns in question 2 we are clearly in a better position than in 1982. We now have reasonable evidence that natural emissions of sulfur oxides are outweighed by man-made emissions in the regions of greatest concern for acid rain. This issue was clarified in the 1982 Annual Report of the Interagency Task Force on Acid Precipitation. And, for nitrogen oxides, recent studies conducted by the Task Force and to be reported in their 1983 Annual Report indicate that as much as 25% of the background levels of NOx may be caused by lightning. There may be an additional amount of NOx contributed by natural sources such as the decomposition of organic matter.

In conclusion, a great deal of additional information is required to address acid rain in a responsible way. The first years of the Task Force research efforts involved the organization and initiation of studies. We are now in the phase of receiving reports and our efforts are paying off handsomely.

At some point, policy makers in the federal government will have to decide that enough scientific research has been completed to take appropriate action. I do not believe we are yet at this point.

APPENDIX F

Answers to Questions Submitted From the Senate Committee on Energy and Natural Resources

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After the hearing on
Acid Rain
April 30, 1984

1. Dr. Christopher Bernabo, Executive Director, National Acid Precipitation Assessment Program. Submitted with answers to questions is the report, "National Acid Precipitation Assessment Program, Annual Report 1983, to the President and Congress". prepared by the Interagency Task Force on Acid Precipitation.

2. Dr. Raphael Kasper, Executive Director, Commission on Physical Sciences, Mathematics, and Resources, National Academy of Sciences.

3. Dr. Bernard Manowitz, Chairman, Department of Applied Sciences, Brookhaven National Laboratory.

Richard

NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM
722 JACKSON PLACE, N.W.
WASHINGTON, D.C. 20506
202/395-5773

Official Committee File

22 June 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
JUN 25 1984
WASHINGTON, D.C. 20510

Mr. Richard Grundy
Committee on Energy and
Natural Resources
United States Senate
Washington, DC 20510

Dear Mr. Grundy,

Enclosed are my responses to the questions from the oversight hearing on April 30. The majority of the responses are based on information that was compiled by experts in the National Program for our 1983 Annual Report to the President and Congress, which I have enclosed for the record. I am sorry for the delay in replying to the questions.

I hope this information adequately addresses the questions that were raised by the Committee members. If you need further clarification, please don't hesitate to call.

Sincerely,

Katie Davis for
Chris Bernabo
Executive Director

Response to Questions

Submitted to Dr. Chris Bernabo
by the
Senate Committee on Energy and Natural Resources

22 June 1984

1. In your September 1983 testimony before the House Science and Technology Committee, you stated that "It is not yet possible to identify the specific change in the acid deposition patterns that would result from a given change in precursor emissions."

   Does this statement remain accurate today? Does this mean that we are still not sure that reducing sulfur dioxide emissions in the Midwest by 50% will reduce acid deposition in New England by 50% or by nearly 50%?

   Response: Based on the limited information available, it is now suggested that, when averaged over the entire eastern half of North America for a year or more, there appears to be nearly a one-to-one (linear) relationship between sulfur dioxide emissions and sulfate deposition. This relationship may not hold true for smaller spatial scales or shorter time frames. A 50% reduction in sulfur dioxide emissions resulting in an overall average 50% reduction in wet sulfate deposition over a large area, does not guarantee a 50% reduction at a specific site. We are still unable to reliably predict deposition at specific sites or over sensitive regions of critical concern.

2. In that same testimony you reported that during FY82 the National Program completed a preliminary study of emission sources which suggested that "nearby petroleum combustion, as well as local and distant coal combustion, could significantly affect local acid deposition".

   Did you study mobile sources as well as stationary sources? Did this study suggest that local petroleum and coal combustion could be causing some of the acid deposition that is being popularly attributed to distant coal combustion?

   Response: This statement refers to the acid precipitation precursor study which used detailed fuel-use data to estimate emissions of pollutants related to acid deposition in the Northeast. Results of this study will be used to help determine the accuracy of information in the emissions data base, which will contain estimates of emissions of sulfur dioxide and nitrogen oxides from all man-made sources at the state level.

3. The recent report of the Ad Hoc Committee to Review the National Acid Precipitation Assessment Program (12/83) suggests that more Federal funding of the Task Force will be required if you are to achieve your statutory objectives in a timely fashion (1985, 1987, and 1989 Assessments). Do you agree with the Ad Hoc (Deutch) Committee's report?

   Response: In any area of research where results are unpredictable, it is always desirable to put as much effort into the work as possible. However, even the Deutch panel advised that about $55 million in FY 1985 (about 100% increase over FY 1984) was as much as the scientific community could effectively spend. In FY 1985, the President's budget request for National Program research is $55.5 million. The Task Force is presently developing its FY 1986 interagency budget proposal, which will be submitted to OMB in September 1984.

4. Let's assume that we in the Congress intended to make public policy regarding any new emissions standards only after we have received sufficient scientific information to assure that any new program we enact is likely to achieve its stated objectives in acid deposition reduction in sensitive areas, rather than in emissions reductions. When will we have sufficient scientific information to make such sound public policy judgments?

   Response: Addressing the acid rain issue effectively requires both research and appropriate environmental policies. The National Program has already produced many important results described in the 1983 and 1982 annual reports. Given the acceleration of research under the National Program, by the private sector, states, and other nations, major strides forward in our understanding can be expected. But objective scientific information is only one contribution, albeit an important one, to developing environmental policies. Policymakers, not researchers, must decide when scientific information is adequate for decisionmaking. The scientists can define at any point in time what is known, with what level of certainty, and what is not yet known.

   Three major assessments, scheduled for 1985, 1987 and 1989, are important milestones for the National Program and the primary focus of the research activities. The dates for these assessments are based on realistic projections of how soon critical information will be available. The scope of the 1985 assessment includes an estimate of the magnitude of current damages, and a summary of the uncertainties surrounding the source/receptor relationship. A more comprehensive, integrated assessment will be produced in 1987 and improved in 1989.

5. What do we know with some scientific assurance about the causes of acid deposition?

   Response: The status of the science is summarized best in our 1983 Annual Report to the President and Congress. Only a few highlights for the northeastern United States are given below.

- Over 90% of the acidity of wet deposition derives from sulfuric and nitric acids. Hence, precursors to acid deposition are most likely SOx and NOx.

- The greatest concentration and deposition of acidic materials (hydrogen ions, sulfate and nitrate) occurs in the Ohio-Pennsylvania-West Virginia area, the region generally within or downwind of very large man-made emission sources of SOx and NOx. This implicates these areas as significant contributors to acid rain.

- There are natural sources of acidic materials but the amount contributed to acid deposition in eastern North America is thought to be small (a few percent), but the actual natural contribution whether negligible or significant, is unknown.

- There is no general correspondence between large variations in acid deposition over eastern North America and small seasonal variations in emissions.

- In places like the Adirondacks, meteorological back trajectories of air parcels associated with the greatest acid deposition usually pass over an arc from southern Michigan southward to West Virginia.

6. What is the relative contribution of man-made versus natural sources of acid deposition?

Response: There is a scientific consensus that man-made emissions have increased the acidity of precipitation over eastern North America, but that existing data and studies do not constitute an adequate basis for determining the details of past patterns in precipitation acidity. The existing literature would suggest that on an annual basis, for the eastern United States, the natural contribution of pre-acidic materials constitute only a few percent of the total, perhaps no more than 10% and probably much less, especially in the northeastern U.S. with the preponderance of man-made sources of sulfur and nitrogen. The natural sources are from both biogenic (e.g., vegetation and microbial activity) and nonbiogenic (e.g., volcanoes, lightning, and airborne particulates in ocean spray and dust) activities. Emissions from natural sources are often poorly quantified. Both natural and man-made sources are being studied intensively under the National Program.

7. What is the relative contribution of wet versus dry acid deposition?

Response: The relative ratio of wet to dry deposition is unknown. Dry deposition may account for 25 to 80% or more of the acidity deposited in some areas. The timing, amount, and composition of this wet and dry deposition can influence the effects on the sentitive receptors. While a national wet deposition network is operational, no standardized scientific techniques yet exist to measure dry deposition on a routine basis. Near the emission sources, dry deposition is believed to be an important contributor, possibly a predominant contributor, of acid-forming substances due in part to rapid settling of heavier particles. The ratio of wet to dry deposition is also very dependent on weather. If there is a period of low or no precipitation over a broad area, clearly the dry deposition would have to be greater than wet, which might be zero due to the lack of moisture. The National Program has accelerated its research effort on wet and dry acid deposition.

8. What is the relative importance of local versus distant pollution sources in controlling the acidity of deposition at a given location?

Response: Most of the acid deposition policy debate has focused on long-distance transport, even though local sources are believed to be significant in many cases. The relative role of local versus distant sources varies greatly among different receptor sites and remains a major uncertainty in evaluating the effectiveness of possible control strategies. As explained in the response to Question 1, we are still unable to reliably predict deposition at specific sites or over sensitive regions of critical concern. The National Program is examining local as well as distant inputs to deposition.

9. What is the temporal and spacial distribution of acid deposition?

Response: In eastern North America, the temporal distribution of sulfate and hydrogen ions in precipitation is a maximum in the warm summer months and a minimum in the winter months. The difference between these times of the year may average as much as a factor of two or more. Because precipitation in eastern North America does not exhibit a very marked seasonal variation, the same summer-to-winter difference in water concentration also applies to the amount of deposition of these two ions. The air concentration of SO_2 is maximum in winter but the air concentration of sulfate is maximum in summer. The nitrate ion, on the other hand, does not appear to exhibit any marked seasonality. The spatial distribution of the above ions are illustrated in the attached figures taken from the U.S.-Canadian MOI report.

10. Is there any indication that acid deposition is accelerating? In other words, are we attempting to deal with an emergency situation?

Response: Wet deposition network data suggest no striking changes in the pH of precipitation during the past several years. While trends of sulfate deposition are still not definitive, the regions of highest deposition for the past few years coincide with the regions where emissions are highest, namely the Midwest and Northeast. Increases in nitrate deposition roughly parallel the increase of man-made emissions of nitrogen oxides.

Historically, indirect evidence of acid deposition over the Northeast from remote surface water stations indicates stable or slightly decreased sulfate with a corresponding increase in alkalinity, during the last 10 to 15 years. A gradual increase in sulfate at some stations of the Southeast and West has also been observed in recent years along with a slight decline in alkalinity. These changes generally coincide with lower overall emissions of sulfur dioxide during the 1970's and increased overall emissions in the Southwest and West.

11. Why is knowing the relationship between emissions and deposition important to the implementation of an acid deposition control program?

Response: The relationship between emissions and deposition is complicated by atmospheric variability and chemical transformations in the atmosphere during transport. Improved understanding of the emission to deposition relationship (also called the source/receptor relationship) is essential for the reliable assessment of the consequences of various control strategies. First, understanding such a relationship would insure that the proper pollutants are being restricted to achieve the desired benefit in deposition. Second, even if the controls took the nature of a uniform roll-back over a broad geographical area, the source/receptor relationship would describe the amount of reduction needed to reduce the deposition on the desired regions (usually called the sensitive areas). Finally, and perhaps most important, if there were a geographically selective program of emissions control, the source/receptor relationship would be invoked to produce scenarios to minimize costs or other impacts in order to achieve reductions in deposition.

12. Is the theory of linearity a proven hypothesis? Do we know whether any of the atmospheric processes involved with acid deposition are non-linear? What is the significance of the linearity debate in acid rain emissions control policy terms?

Response: The theory of a one-to-one (linear) relationship between sources and receptor is not proven, except in an extreme case: When considered globally and over many years, the axiom that what goes up must come down is true as far as emissions are concerned. The uncertainty focuses on when, where, and in what form emissions are deposited on less than global spatial scales and over shorter time periods. Taken on a practical broad scale of space (eastern North America) and time (one year), it is now suggested that when averaged the relationship between sulfur dioxide emissions and sulfate deposition is approximately one to one (as proposed in the National Academy of Sciences' recent report). However, when small areas for sources or receptors are considered, evidence for or against linearity is absent.

Because of the existing uncertainties surrounding the source/receptor relationship, actual proven cases of non-linearity in the real atmosphere cannot be sited. It should be noted that wet sulfuric acid deposition requires a mechanism for oxidation of SO_2 to SO_4. If the atmosphere should be devoid of such oxidants or catalysts, the conversion will not occur irrespective of the amount of SO_2 present. Hence, the amount of acid deposition would be unrelated (non-linear) to the amount of emissions. The one example of a significant reduction in an SO_2 source occurred at Sudbury, Ontario, when the INCO smelter was shutdown. Yet from analysis of the data no clear reduction in sulfate concentration in precipitation could be discerned. The results from the recent shutdown are still being analyzed.

The significance of the linearity debate is that we are still unable to reliably predict deposition at specific sites or over sensitive regions of critical concern. This complicates designing optimized control strategies or providing strong assurances that a given reduction in emissions will result in a specified environmental benefit.

13. What are the direct and delayed response theories? Do we know whether or not acid deposition has reached such proportions in sensitive ecosystems that equilibrium has been reached? What are the postulated consequences of acid deposition on poorly buffered soils versus well buffered soils?

Response: Wet and dry deposition of acid and acidifying substances typically pass through the vegetation canopy and over or slowly through soils before entering water bodies. At any point along this pathway, various processes can neutralize the acidity of the precipitation. Many terrestrial systems offer sufficient neutralizing capacity to prevent the bulk of most highly acidified precipitation from entering a water body in an acidic form. In addition, runoff from agricultural activities may be expected to overwhelm natural inputs in some areas.

For lakes characterized as nutrient-poor, surrounded by thin (or no) soils underlain by granite, with steep slopes, it appears that acid deposition consumes the acid-neutralizing capacity of the watershed and the associated water bodies to a point at which acidification can occur. In such cases, once the neutralization capacity is reduced, surface water quality will resemble precipitation chemistry within years to decades. Surface waters with these response characteristics have been identified in a few areas in the United States, and represent one category of waters and watersheds commonly referred to as "quick response" systems (changing in time frames of years to decades). Quick response systems represent the most sensitive class of surface waters. In contrast to these systems are "no response" systems (subject to change in time frames of centuries or millenia). Between these two extreme types of surface water systems are those referred to as "delayed response" systems (subject to change in time frames of decades to centuries). The major processes of acidification are described in detail in our 1983 Annual Report (p 15).

14. How long might it take before the National Program research efforts on acid precipitation might provide some substantive results upon which policy decisions pertaining to acid rain control might be made?

Response: As Congress recognized in creating this long-term, broad-based program, the issue is exceedingly complex and has required advancing the frontiers of science in fundamental areas of ecology and atmospheric sciences. The National Program has already produced important results, but definitive answers to some key questions are not yet available. Fortunately, given the acceleration of research under the National Program, by the private sector, states, and other nations, major strides forward in our understanding are expected in the coming years. While the information base will gradually be improved, it will never be made absolute. Therefore policymakers, not researchers, must decide when scientific information is adequate for decisionmaking. Enhanced scientific understanding can only strengthen our confidence in selecting the most effective actions to yield the desired environmental results. (Also see response to Question 4.)

15. Do we know what changes in deposition would result from a given change in sulfur oxides (or primary sulfate), nitrogen oxides, and/or organic compounds?

Response: This question represents the thrust of the work on the source/receptor relationship. There are now 10 to 20 mathematical simulation models in the United States and elsewhere which purport to provide predictions of the deposition change one would expect in sulfate from reductions in SO_2 or SO_4. There are many fewer models dealing with NOx and probably none (or virtually none) treating the hydrogen ion and organic compounds. These models, in some instances, yield highly different results even when given the same emissions and sets of meteorological conditions. Some models reproduce observed wet sulfate deposition rather well. But the verification fails to include the deposition in one area from a single source area because there is no observed data to use for verification. Further, although the models predict dry deposition and air concentration, there is no verification data for these elements either. Thus, the most straightforward answer about the present state of source/receptor relationships: There are now models (for at least sulfur compounds) which can make predictions of changes in deposition from reductions in emissions, but it is not known whether those predictions are correct.

16. How will the research the Interagency Task Force is presently doing to monitor trends and interpret historical data relating to acid deposition and the nature of this phenomenon help in policy decisions on how to deal with this problem?

Response: While there is a scientific consensus that man-made emissions have increased the acidity of precipitation over eastern North America, the existing data and studies do not constitute an adequate basis for determining the details of past patterns in precipitation acidity. Problems with earlier determination of pH and other factors have called into question previous attempts to define specific rates and patterns of increased precipitation acidity in eastern North America. Monitoring and research efforts are now underway that will allow improved interpretation of historical data and confident assessment of future trends.

Monitoring of acid deposition will help in policy decisionmaking in several ways. First, if there are trends in emissions of pre- acidic material, the monitoring results will be the most convincing evidence of the nature of the response. During the 1970's there was a decrease in SOx emissions and an increase in NOx emissions. The limited data do suggest similar trends in deposition, but the lack of adequate monitoring prevents one from making more definitive statements. The expanded National Trends Network (NTN) program of NAPAP can correct this. If a clear positive (or even ambiguous) response in deposition from emission changes with time, this would influence any policy decision. Second, if it is decided that acid deposition damage (if any) is acceptable so long as the level of acid deposition does not increase, the urgency for emission controls would be influenced. Finally, a monitoring network is needed even after emission controls are imposed (if they should be) in order to assess any benefits from such actions.

17. Why is understanding the rate of change as it pertains to the acidification of terrestrial or aquatic ecosystems important? How would a greater understanding of the rate of change affect our ability to do something about the problem?

Response: In part the urgency to take action to control emissions or to adopt appropriate mitigation strategies depends upon knowing if the ecological changes have stabilized or are deteriorating even further. If the damage is progressing at a rapid rate, then this might be considered a reason for urgent action to prevent further deterioration. If, on the other hand, the situation has stabilized or the rate of change is not very great, the need for urgent action might not be warrented. Enhanced scientific understanding can only strengthen our confidence in selecting the most effective actions to yield the desired environmental results.

18. If SO_2 emissions were reduced by 10 million tons in the Midwest, do we know whether or not that reduction would in any way affect the mechnaisms of action of acid deposition on forest growth? If, as your statement suggests, the problem is from combined pollutant effects on foliage, or even soil-mediated processes, could the control of just one possible causitive factor such as SO_2 in any way exacerbate damage from any other possible chemical or non-chemical factor, such as ozone, for example?

Response: As explained in detail under Questions 1 and 12, we are still unable to reliably predict deposition at specific sites or over sensitive regions of critical concern. Therefore, we cannot determine the results that a cutback in emissions (e.g., 10 million tons) would have on the amount of deposition in a particular area.

Some forests in North America and Europe are showing environmental stress, the causes of which are a topic of scientific debate. Although natural factors may be involved, they alone do not seem to explain adequately the observed changes. New hypotheses to explain forest decline are being generated and tested systematically. These hypotheses involve various pollutants acting alone or in combination, such as sulfur dioxide, nitrogen oxides, trace metals, ozone, and acid deposition. Even this list of possible agents involved in the decline should not be considered complete because the association between damage and the occurrence of these pollutants is not well defined. Available evidence seems to support combined pollutant effects on foliage, although soil-mediated processes cannot be ruled out at this time. A variety of complex causes is possible and plans for accelerated work are underway to determine which factors -- such as acid deposition, gaseous pollutants, insects, disease, or drought -- contribute to the observed damages.

19. Why is understanding the mechanisms of acid deposition and quantitatively evaluating the processes involved important to the implementation of an acid deposition control program?

Response: The understanding of mechanisms in the acid rain issue is vital to avoid spending large amounts of money, dislocating industry and workers, etc. without a reasonably firm foundation that the action will produce the desired benefits.

20. What do we know with some scientific certainty about the effects of acid deposition on aquatic resources, crops, soils, forests, materials, or human health? What are the scientific uncertainties or theories in disagreement in these areas?

Response: This question is addressed in detail in the introductory section of the 1983 Annual Report (p 13-17), as well as in my response to other questions submitted by the Committee. I will only attempt to highlight the various areas below.

- Some lakes in sensitive regions have been acidified and have experienced fisheries loss; however, the rate, character, and full extent of these changes remain major scientific unknowns. Few aquatic systems have been studied in sufficient detail to document the actual changes. (See Question 13.)

- Recent research and survey results have tended to reduce concern about acid deposition damage to crops while increasing general concern about possible effects on forests. (See Question 18.)

- Rates of corrosion and degradation of building material can be accelerated by increased acidity. However, information about effects on materials from acid deposition needs to be better defined, including the extent of materials damage attributable to man-made pollutants, the rate of degradation, a quantitative evaluation of the processes involved, and a reliable estimate of the materials at risk.

- The direct effects on human health of inhaling sulfate particles and aeorsols continue to be studied under other pre-existing Federal programs. Studies in the National Program of acid deposition's relationship to human health focus on the new area of indirect effects after these substances are deposited. In this context, no significant indirect human health effects have yet been documented in the United States as being a consequence of the deposition of acid.

There is ongoing effects research under the National Program in all these areas.

21. What will be gained from the National Lakes Survey?

Response: The National Lakes Survey is part of a systematic survey of both lakes and streams in the United States. Outputs from the survey will be very useful to the National Program. Specifically, it will (1) quantify the extent of sensitive aquatic resources; (2) quantify the amount of surface water that is acidic (from any cause); and (3) provide a data base from which to predict future changes in surface water chemistry and biota based on changes in deposition rates.

22. I am intrigued by the Task Force finding in FY82 that local petroleum combustion could significantly affect local acid deposition. Were you able to quantify the contribution of local petroleum combustion (such as from automobiles, utility boilers and industrial uses) to local acid deposition? If we cannot quantify the contribution of local petroleum combustion, then is it also true that we cannot quantify the contribution of distant and local coal combustion to acid deposition as well?

Response: The preliminary 1980 emissions estimates compiled by the National Program, which are outlined below, indicate that electic utilities are by far the largest source of sulfur dioxide in the United States, followed by other forms of industrial combustion. Although metal smelters are not a major source nationally, they are important on a local level. The largest single source of nitrogen oxide emissions in transportation related activity, followed by electric generation and other industrial combustion. "Other" in the table includes other industrial processes and residential commercial fuel use.

Table B–1. National emissions estimates in the National Program's 1980 Emissions Inventory* (Millions of Tons)

	Sulfur Dioxide	Nitrogen Oxides
Utilities	18.6	8.0
Industrial Combustion	4.6	3.0
Smelters	1.2	—
Transportation	0.8	8.7
Other	2.4	3.1
TOTAL	27.6	22.8

*NOTE: Task Group B is reviewing the data in its 1980 Emissions Data Base, and will release the final version of this data in 1984. The data represented in Table B-1 have undergone a preliminary review for inconsistencies; these inconsistencies are being corrected. Until the final version of the emissions data base is released, these emissions should be used with caution.

23. Most of the recent concerns over acid deposition and emissions has focused on the acidification of certain lakes in the Adirondack Mountains of New York. However, in your September 1983 testimony before the House Science and Technology Committee, you stated: "At present, the extent of actual aquatic damages is not well established. The question of long-term trends in freshwater acidification also remains uncertain." Will the National Program be able to establish both the actual aquatic damage attributable to acid deposition and the trend in freshwater acidification and its causes? When?

    Response: Acid deposition has been identified in some scientific reports as contributing to both long- and short-term depressions in pH and reducing alkalinity in some lakes and streams in the United States. Only a very small percentage of U.S. lakes and streams are thought to have lost all alkalinity because of acid deposition. Clear relationships have not been established between acid deposition and observed aquatic effects. The actual aquatic damage attributable to acid deposition will be described with some degree of certainty in the 1985 Assessment, and with increased certainty in the 1987 and 1989 integrated assessments.

24. The Ad Hoc Committee to Review the National Acid Precipitation Assessment Program (NAPAP) filed its report in December 1983. That report included a number of recommendations for improving the program. Are these recommendations being implemented?

    Response: The Interagency Task Force has reviewed all the recommendations of the Ad Hoc Committee, and has implemented several management and organizational changes based on the recommendations.

25. One of the harshest criticisms of the Ad Hoc Committee was the funding levels requested by the Administration. Did you bring the funding level criticisms to the attention of the proper officials, including the OMB? Will the Administration request the increased funding recommended by the Committee?

Response: As noted in my answer to Question 3, the Ad Hoc Committee independently suggested that about $55 million was the amount that could be spent effectively in FY 1985. The President's FY 1985 budget request of $55.5 million for the National Program represents a 100% increase over FY 1984. The FY 1986 interagency budget for the program, which is now being developed, will be submitted to OMB in September 1984 for approval, before it is included in President's budget request to the Congress.

National Acid Precipitation Assessment Program

Annual Report 1983 *to the President and Congress*

Prepared by the
Interagency Task Force on Acid Precipitation

Annual Report, 1983

Department
of Agriculture

National
Oceanic and
Atmospheric
Administration

Environmental
Protection Agency

Council on Environmental Quality • Department of Commerce • Department of Energy
Department of Interior • Department of Health and Human Services • Department of State
National Science Foundation • National Aeronautics and Space Administration
Tennessee Valley Authority

Washington, D.C.

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Summary

The goal of the National Acid Precipitation Assessment Program is to develop and progressively improve on an objective and comprehensive information base for use by decisionmakers. This statutory Annual Report to the President and Congress outlines the specific accomplishments of the National Program during the last year (FY 1983), summarizes the current state of scientific knowledge for decisionmakers, and describes the outlook for continued progress by the federally sponsored research effort on acid deposition.

In establishing the National Program in late 1980, the Congress recognized both the urgency of the issue and the long-term need for research to address it adequately. The statutory program was given a 10-year renewable mandate with annual reporting duties. The need to bring together the many important producers and users of acid deposition information was also recognized, with 12 Federal entities united to work together. This long-term and broad-based approach was recognized as essential in order to tackle effectively the great complexity of the acid precipitation issue.

The National Program has received increased funds, up from $18 million in FY 1982 to $27 million in FY 1984 and with over $55 million requested for FY 1985. In 1983, the second full year of research under the National Program, our activities entered a new phase. During 1981 and 1982 emphasis was on planning and organizing the comprehensive program. Now work is well underway and the emphasis is shifting toward producing results and working with the users of the information. Major peer reviews of all the work — over 250 projects — have been completed. National meetings and workshops have brought the producers and users of acid deposition information together. Great strides have been made in building and focusing the comprehensive program on the key scientific questions most relevant to decisionmakers' needs. A continuing dialog has been established to provide feedback between decisionmakers and scientists so that the work remains relevant and the strengths as well as limitations of the planned research are better understood.

Information on acid deposition has many different and important uses, and the National Program thus has a diverse clientele. Primary emphasis is, of course, on meeting the urgent needs of the Congress and Executive Branch decisionmakers who are charged with developing sound environmental policies for the Nation. Most attention in the public debate has focused on information relevant to determining regulatory policy about sulfur dioxide and, to a lesser degree, nitrogen oxide emissions.

There are many other uses of the information beyond determining emissions control policies. Acid deposition information is needed by resource managers responsible for stewardship of lakes, forests, crops, wildlife, and cultural monuments; by Federal and private sector managers of energy resources; and by public, environmental, professional, and trade organizations in formulating their positions and activities. Decisions for which acid-deposition-related information is valuable are made daily in these many areas, and the National Program is dedicated to providing better information for each of them.

STATE OF THE KNOWLEDGE

The acid rain debate has steadily intensified, causing increased demands for authoritative information and heightening the emotionalism surrounding the issue. The National Program is addressing these urgent demands for information while maintaining the essential objectivity that is central to its scientifically-oriented, policy-neutral mandate. The demand for providing "best guesses" based on current information must be balanced against the need to perform only technically defensible analyses and to avoid conjecture. Many scientific uncertainties remain while the demands for definitive answers mount. However, the value of the National Program is no greater than its scientific credibility, and that must be maintained by rigorous technical analysis and adequate peer reviews.

Our understanding of the acid deposition phenomenon is rapidly evolving as research yields new results and old data are re-analyzed in light of new information. Some highlights of the changing state of scientific knowledge are described briefly here, then discussed in more detail in the section "Evolving Science of Acid Deposition."

Relationship Between Emissions and Deposition

Based on the limited information available, it appears that when averaged over the entire eastern half of North America for a year or more, a nearly one-to-one (linear) relationship exists between sulfur dioxide emissions and wet deposition of sulfate. Over smaller time and space scales, though, this relationship may not hold. For instance, a 50 percent reduction in sulfur dioxide emissions in eastern North America may result in an overall average 50 percent decrease in the deposition of sulfur compounds. The precise relationships between emissions and deposition are still unknown, with existing atmospheric models having uncertainties in their predictions of up to tenfold. Extensive research is being done by the National Program to improve our ability to predict more accurately the relationship between emissions and deposition.

There is a scientific consensus that man-made emissions have increased the acidity of precipitation over eastern North America, but that existing data and studies do not constitute an adequate basis for determining the details of past patterns in precipitation acidity. Problems with earlier determination of pH and other factors have called into question previous attempts to define specific rates and patterns of increased precipitation acidity in eastern North America. Monitoring and research efforts are now underway that will allow improved interpretation of historical data and confident assessment of future trends.

Effects of Acid Deposition

Some lakes in sensitive regions have been acidified and have experienced fisheries loss; however, the rate, character, and full extent of these changes remain major scientific unknowns. Few aquatic systems have been studied in sufficient detail to document the actual changes. Recent research has made it clear that the vegetation and soils surrounding a lake or stream play a major role in determining the rate and nature of the water body's response to acid deposition.

Many lakes in North America have complex watersheds where precipitation flows through forest canopies and soils, and is chemically modified before entering the lake. As rain passes over vegetation and through the soils, its acidity can be reduced or increased manyfold. Some watersheds may be vulnerable on the time scale of decades, while some others probably have the capacity to neutralize for centuries acid precipitation of the strength now falling. Surveys and detailed studies are underway or planned to determine and to predict the rates of change, and identify the most vulnerable aquatic resources.

Recent research and survey results have tended to reduce concern about acid deposition damage to crops, while increasing general concern about possible effects on forests. Sulfur and nitrogen, the basic ingredients of acid rain, are applied to crops by farmers in fertilizers at many times the rate they are deposited by precipitation. The few relevant studies to date suggest the most commonly planted varieties of crops are not highly susceptible to acid deposition, although some cultivars have shown reduced yield. Laboratory and field studies are being conducted to assess more completely the effects of actual acid deposition on crops.

Some forests in North America and Europe are showing environmental stress, the causes of which are a topic of scientific debate. Evidence analyzed during the past 3 years indicates that significant changes in growth and vitality of some species have occurred in the eastern U.S. forests. Based on regional assessment of both mortality and growth declines, it is apparent that a systematic and sustained growth decline of some species has occurred in the last 20 to 30 years. Extensive dieback and decline of red spruce has occurred in some high elevation forests of New England, resulting in up to 60 percent mortality in some stands.

Growth reductions and increased mortality are also evident in the southern Appalachian mountains, including North Carolina and Tennessee. The symptoms of decline of red spruce in New England and of Norway spruce in Germany appear similar in some respects and very different in others. The observed changes include initial loss of needles from the top and outside the canopy with gradual loss of vigor of the tree, slowed growth, and ultimately, mortality. Growth of other species, principally fir and pitch and shortleaf pine, has decreased significantly within the past 20 years in the Northeast. It appears that forests in the United States may be responding to stresses that have been occurring for the past two to three decades.

Although natural factors may be involved, they alone do not seem to explain adequately the observed changes. New hypotheses to explain forest decline are being generated and tested systematically. These hypotheses involve various pollutants acting alone or in combination, such as sulfur dioxide, nitrogen oxides, trace metals, ozone, and acid precipitation. Even this list of possible agents involved in the decline should not be considered complete because the association between damage and the occurrence of these pollutants is not well defined. Available evidence seems to support combined pollutant effects on foliage, although soil-mediated processes cannot be ruled out at this time. A variety of complex causes is possible and plans for accelerated work are underway to determine which factors — such as acid precipitation, gaseous pollutants, insects, disease, or drought — contribute to the observed damages.

The Federal Republic of Germany has documented forest damage that appears to be increasing. Initial hypotheses focused on acid deposition and aluminum toxicity in soils as the main culprits. Recently, other factors, such as direct exposure to gaseous air pollutants, have been hypothesized to be the causes. International efforts are underway to work cooperatively in determining the causes, character, and extent of the observed forest changes in Europe and North America.

Rates of corrosion and degradation of building material can be accelerated by increased acidity. However, information about effects on materials from acid deposition needs to be better defined, including the extent of materials damage attributable to man-made pollutants, the rate of degradation, a quantitative evaluation of the processes involved, and a reliable estimate of the materials at risk. Under the National Program, an inventory of materials at risk in the United States is being compiled, and other crucial analyses are underway.

As science advances our understanding of the acid rain issue, data are collected and analyzed, and many different hypotheses are proposed to explain the observed phenomena. Experiments must be designed to test the scientific validity of the various possible explanations. The existence at any one time of several possible explanations can confuse the issue and dismay decisionmakers and the public. But scientific inquiry into complex environmental issues rarely, if ever, can provide simple clear-cut answers. The search for understanding is often laborious, while the demands on policymakers are urgent and immediate. The public and decisionmakers understandably become impatient. Yet, only by careful research can a better information basis for decisions be developed.

PROGRAM ACCOMPLISHMENTS

The National Program has resulted in many specific accomplishments during FY 1983, the second year of research. Some of these, briefly highlighted here, are discussed in greater detail in the Research Progress and Outlook section of this report. The major activities of the National Program's 10 task groups are shown in Figure 1. Significant advances during 1983 were as follows:

Natural Sources

- Measured sulfur compounds in the Gulf of Mexico and northern Pacific Ocean.

  Significance: Quantifies the potentially important contribution of natural sulfur compounds in seawater.

- Modeled photochemistry induced by lightning to assess this source of natural nitrogen oxide emissions.

  Significance: Quantifies nitrate contribution from lightning as a significant portion of total natural background (approximately 25 percent).

- Developed and tested a fast response nitric oxide chemiluminescence detector.

  Significance: Enables measurements at the low concentrations seen in nature and allows direct measurement of changing rates in an area for the first time.

Man-made Sources

- Completed a preliminary draft of an improved 1980 Emissions Data Base for sulfur dioxide, nitrogen oxides, total volatile organic compounds, and particulate matter emissions for point sources and area sources in the 48 contiguous States.

  Significance: Improves data base for updated models and assessments.

- Developed a State-level version of the Advanced Utility Simulation Model.

  Significance: Facilitates regional forecasts of emissions and of control costs.

Atmospheric Processes

- Participated with Canada in the Cross Appalachian Tracer Experiment (CAPTEX) that tracked clouds of inert tracer across northeastern North America.

  Significance: Will assist in verifying modeling of long-range transport and dispersion.

- Conducted long-range air transport studies of dust and other materials to track air mass movement in different parts of the world.

  Significance: Helps evaluate significance of long-distance transport of pollutants to remote regions.

- Measured sulfur and nitrogen dry deposition over a variety of surfaces and under various atmospheric conditions. Continued to develop fast-response sulfur and nitrogen sensors to measure their fluxes.

  Significance: Helps derive mathematical descriptions based on field data of dry deposition for simulation in numerical models.

- Modeled wet and dry deposition of sulfur using the Advanced Statistical Trajectory Regional Air Pollution model for 1980 and 1981 to derive statewide annual deposition maps.

  Significance: Refines regional deposition maps for comparisons of impacts.

- Developed an airborne, two wavelength lidar (luminescent) system that can locate specially tagged air masses long distances from sources.

  Significance: Allows pollution plume tracking over long distances.

Deposition Monitoring

- Installed 17 new stations in the National Trends Network.

  Significance: Fills gaps in wet deposition monitoring data base.

- Tested new equipment to develop sequential precipitation samplers, to study fog removal of particles from the air, to determine the origin of acidity in remote areas, and to assess diurnal and seasonal variations in acidity.

  Significance: Improves the reliability and breadth of special studies.

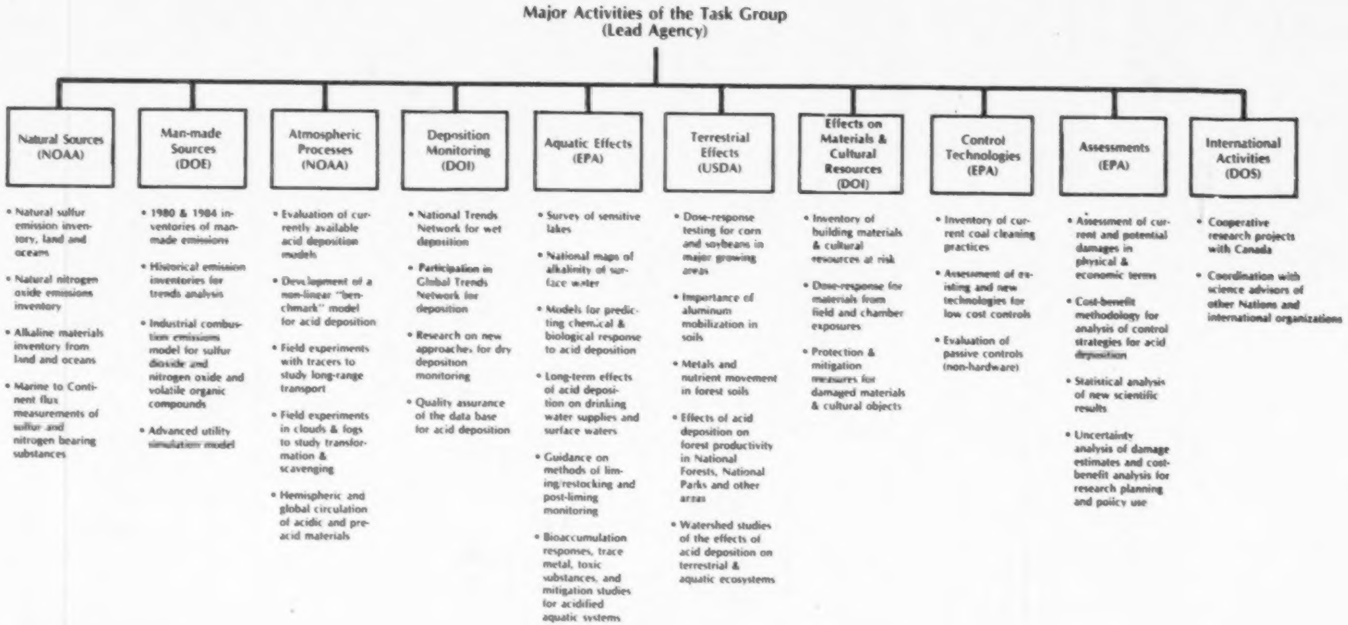

Major Activities of the Task Group (Lead Agency)
Natural Sources (NOAA)
• Natural sulfur emission inventory, land and oceans
• Natural nitrogen oxide emissions inventory
• Alkaline materials inventory from land and oceans
• Marine to Continent flux measurements of sulfur and nitrogen bearing substances
Man-made Sources (DOE)
• 1980 & 1984 inventories of man-made emissions
• Historical emission inventories for trends analysis
• Industrial combustion emissions model for sulfur dioxide and nitrogen oxide and volatile organic compounds
• Advanced utility simulation model
Atmospheric Processes (NOAA)
• Evaluation of currently available acid deposition models
• Development of a non-linear "benchmark" model for acid deposition
• Field experiments with tracers to study long-range transport
• Field experiments in clouds & fogs to study transformation & scavenging
• Hemispheric and global circulation of acidic and pre-acid materials
Deposition Monitoring (DOI)
• National Trends Network for wet deposition
• Participation in Global Trends Network for deposition
• Research on new approaches for dry deposition monitoring
• Quality assurance of the data base for acid deposition
Aquatic Effects (EPA)
• Survey of sensitive lakes
• National maps of alkalinity of surface water
• Models for predicting chemical & biological response to acid deposition
• Long-term effects of acid deposition on drinking water supplies and surface waters
• Guidance on methods of liming/restocking and post-liming monitoring
• Bioaccumulation responses, trace metal, toxic substances, and mitigation studies for acidified aquatic systems
Terrestrial Effects (USDA)
• Dose-response testing for corn and soybeans in major growing areas
• Importance of aluminum mobilization in soils
• Metals and nutrient movement in forest soils
• Effects of acid deposition on forest productivity in National Forests, National Parks and other areas
• Watershed studies of the effects of acid deposition on terrestrial & aquatic ecosystems
Effects on Materials & Cultural Resources (DOI)
• Inventory of building materials & cultural resources at risk
• Dose-response for materials from field and chamber exposures
• Protection & mitigation measures for damaged materials & cultural objects
Control Technologies (EPA)
• Inventory of current coal cleaning practices
• Assessment of existing and new technologies for low cost controls
• Evaluation of passive controls (non-hardware)
Assessments (EPA)
• Assessment of current and potential damages in physical & economic terms
• Cost-benefit methodology for analysis of control strategies for acid deposition
• Statistical analysis of new scientific results
• Uncertainty analysis of damage estimates and cost-benefit analysis for research planning and policy use
International Activities (DOS)
• Cooperative research projects with Canada
• Coordination with science advisors of other Nations and international organizations

Figure 1. Major activities of the National Acid Precipitation Assessment Program

- Established three dry deposition field research sites in conjunction with the Atmospheric Processes Task Group.

  Significance: Provides prototypes for development of a national dry deposition measurement network.

- Established an Acid Deposition System for data base management of all acid deposition monitoring sites in North America.

  Significance: Permits more timely and comprehensive data analyses.

Aquatic Effects

- Completed an inventory of existing water quality data on the lakes, streams, and ground waters of the United States to assess the extent and degree of sensitivity to acid deposition.

  Significance: Provides a baseline for damage assessment.

- Established a network of long-term monitoring stations at lakes and streams across the country to correlate changes in water quality and deposition.

  Significance: Improves ability to detect changes over time.

- Began a controlled lake acidification field experiment.

  Significance: Improves understanding of mechanisms of biological and chemical effects.

- Initiated laboratory and field tests to lime lakes sensitive to acid deposition.

  Significance: Develops better techniques for offsetting of acidification damage.

- Studied the quality of drinking waters and source waters in the Northeast for mobilization of heavy metals at different pH levels to determine possible indirect health effects associated with acid deposition.

  Significance: Preliminary results indicate many of the waters surveyed are corrosive but levels of metals did not exceed EPA maximum allowable concentrations.

Terrestrial Effects

- Initiated a major study of forest productivity in the eastern United States.

  Significance: Suggests significant patterns of growth reduction for several species at numerous locations, but causes remain uncertain.

- Studied trace element accumulation in tree rings over long-term cycles.

  Significance: Provides insight into historic deposition patterns by correlating iron accumulation with emissions.

- Conducted studies of the effects of simulated acid rain on seedlings of yellow poplar, loblolly pine, red spruce, and other sensitive species.

  Significance: Indicates no effects at or above pH 3.6.

- Conducted forest soils studies.

  Significance: Shows large variation in the physical and biological ability of soils to buffer acid deposition, to convert sulfate to less mobile sulfur compounds, or to leach metals from the soil because of sulfate deposition.

- Conducted sophisticated field tests of simulated acid rain effects on crops.

  Significance: Shows little change in productivity of corn, soybeans, or potatoes. One soybean variety showed an 8 percent reduction at pH 5.6-4.2.

Effects on Materials and Cultural Resources

- Completed a broad study of tombstones cut from the same or similar quarries over the last several decades.

  Significance: Shows significantly more damage in urban areas where local sources of pollutants are most concentrated.

- Established four field exposure test sites to define the deterioration rates of Indiana limestone, Vermont marble, and seven metals. Simultaneous measurement of meteorological conditions, wet acid deposition, air quality, and wetness is part of the exposure test program.

  Significance: Provides a baseline for scientific analysis of corrosion and weathering of building materials.

- Initiated an inventory of distribution of common building materials and cultural properties.

  Significance: Provides a data base for assessing total materials damage.

- Began project to compile service life and cost data on major construction materials and components.

  Significance: Provides more realistic cost estimate for incremental effects of acid deposition.

Control Technologies (funded under other preexisting programs)

- Documented performance tests of the adipic-acid-enhanced limestone flue gas desulfurization (FGD) which allows greater than 90 percent sulfur dioxide control from high-sulfur coal applications.

  Significance: Reduces cost, increases removal efficiency, and improves reliability of limestone FGD.

- Developed an advanced heavy oil burner for industrial boilers that can reduce nitrogen oxides by 85 percent, and when applied commercially should be widely effective.

  Significance: Lowers cost of controlling acid-forming nitrogen oxides.

- Improved capture of sulfur dioxide has been made possible by development of more active limestone sorbent for use with Limestone Injection Multistage Burner process.

  Significance: Allows for potentially more cost-effective control of sulfur dioxide.

Assessments

- Prepared "The Critical Assessment Review Papers" on the state of the science of acid rain.

  Significance: Brings together in one document a summary of past studies and analyses about acid rain effects and damage.

- Adapted the Advanced Utility Simulation Model for use in the integrated assessment methodology.

  Significance: Integrates the use of models with overall assessment of impacts.

- Developed an integrated assessment methodology for future assessment of impacts from acid deposition.

  Significance: Provides a framework for assessing the combined influences of acid deposition on ecosystems.

International Activities

- Met with the Canadian Research and Monitoring Coordinating Committee to review ongoing bilateral projects and to discuss future joint activities.

  Significance: Expands bilateral cooperation in acid rain research, including adopting 12 new U.S.-Canadian projects.

- Met with representatives from the research effort in the Federal Republic of Germany to arrange an exchange of U.S. and German scientists and to develop cooperative research.

  Significance: Increases exchange of information and begins planning of cooperative research.

- Jointly sponsored international conference on forest damages with Canadians.

  Significance: Brought together experts on this important topic to share information and plan cooperative research.

- Participated in several international organizations concerned with acid deposition, such as the U.N. Economic Commission for Europe.

  Significance: Establishes greater cooperation and planning for international acid rain research efforts to address the issue and share information.

Program Management Activities

- Conducted peer reviews of research projects to evaluate the adequacy and comprehensiveness of the National Program.

  Significance: External experts examined the program for scientific quality, relevancy, and interrelationships of research projects.

- Convened a group of acid deposition information users and producers for the second annual meeting with the theme of "Research to Assist Decisionmaking."

  Significance: Developed guidance for the National Program in providing scientific information to decisionmakers.

- Increased coordination and cooperation between Federal research efforts and the research activities of State and local governments, the private sector, and environmental organizations.

  Significance: Helped build a nationwide effort to address the issues effectively.

- Initiated the Coordination Working Group for Atmospheric Field Experiments.

  Significance: This group of Federal, private sector, and Canadian researchers assures timely communication among separate research programs to promote the integrated planning of large-scale field studies of the relationship between pollutant emission sources and acid deposition.

THE ROLE OF SCIENCE

The research and monitoring activities of the National Program are providing successively better tools and a continually improved information base for developing and implementing sound policies to achieve the maximum environmental benefit at minimum cost to society. As Congress recognized in creating this long-term, broad-based program, the issue is exceedingly complex and has required advancing the frontiers of science in fundamental areas of ecology and atmospheric sciences.

Addressing the acid rain issue effectively requires both research and appropriate environmental policies. Objective scientific information is only one contribution, albeit an important one, to developing environmental policies. Policymakers, not researchers, must decide when scientific information is adequate for decisionmaking. The scientists can define at any point in time what is known, with what level of certainty, and what is not yet known.

Issues policymakers must also address require making a host of subjective judgments for which scientists have no special expertise. For example, scientists have the task of relating the response of ecosystems to the amount of acid deposition they receive; but it is the role of the policymaker to determine whether emissions should be limited, and by how much, considering the social costs and benefits of prescribed actions.

Although one major goal of the National Program is to quantify such costs and benefits, often they cannot be quantified reliably, and subjective value judgments must supplement scientific analyses. Science does not provide a basis for making such value judgments — those judgments are the role of the policymaker. However, enhanced scientific understanding can strengthen our confidence in selecting the most effective actions to yield the desired environmental results.

The National Program has already produced many important results described in this and the 1982 Annual Report. Given the acceleration of research under the National Program, by the private sector, States, and other Nations, major strides forward in our understanding can be expected.

Introduction

The Interagency Task Force on Acid Precipitation (Task Force) is required by law to issue an Annual Report to the President and Congress describing the progress of the National Program. The Task Force's first Annual Report, issued in January 1982, with research barely underway, primarily discussed the development of the management structure and the plans for the program.

The 1982 Annual Report to the President and Congress, published in June 1983, covered the Task Force's first full year of research. The 1982 report summarized the status of scientific knowledge, the major research findings and accomplishments of the National Program's first year, and the outlook for continued progress.

This report summarizes the major scientific issues that were addressed by the National Program in 1983, and the progress of researchers in reducing the uncertainties of assessing causes, effects, and management of acid deposition. This report particularly emphasizes major research findings that will provide better information to legislators, regulatory officials, resource managers, private sector decisionmakers, and the public to deal with the acid precipitation issue.

The report has four parts. Part one preceding this section summarizes the progress and accomplishments of the National Program. This introduction provides information about the Task Force's and National Program's history, organization, funding, and management. Part three discusses the evolving science of acid deposition and discusses the significant changes in our understanding that have developed as the result of new research findings. The final part contains a detailed overview of the progress and specific accomplishments within each research area of the National Program. The overviews in part four are the core of this report. Within each research area's overview section are examples of the accomplishments, discussion of the research goals, and proposed future activities.

BACKGROUND

The Acid Precipitation Act of 1980 (Title VII of the Energy Security Act, P.L. 96-294) established the Task Force to develop and implement a comprehensive National Program. The purpose of the National Program is to increase our understanding of the causes and effects of acid deposition. The program includes research, monitoring, and assessment activities that emphasize the timely development of a firmer scientific basis for decisionmaking.

The Task Force plans and manages the implementation of the National Program. The Task Force is jointly chaired by the National Oceanic and Atmospheric Administration (NOAA), the Environmental Protection Agency (EPA), and the Department of Agriculture (USDA). The other participating Federal agencies are the Departments of the Interior (DOI), Health and Human Services (HHS), Commerce (DOC), Energy (DOE), and State (DOS); the National Aeronautics and Space Administration (NASA); the Council on Environmental Quality (CEQ); the National Science Foundation (NSF); and the Tennessee Valley Authority (TVA). The Task Force also includes four presidential appointees and the directors of DOE's Argonne, Brookhaven, Oak Ridge, and Pacific Northwest National Laboratories.

The main responsibilities of the Task Force are:

- overseeing and implementing the long-term comprehensive research program that coordinates and focuses the research activities of all the Federal agencies;
- issuing an annual report to the President and Congress on the status of science and research progress;
- maintaining the inventory of all federally-sponsored acid deposition research projects;
- developing and updating the Operating Research Plan of the National Program;
- developing an annual interagency budget for the Federal program;
- ensuring that research projects are technically sound and credible through peer reviews by the scientific community; and

- encouraging productive interaction between the Federal, private sector, academic, State and local government, and international acid precipitation research programs.

The Task Force's role in developing the annual interagency budget is an important responsibility. Historically, this budget has risen from about $11 million in FY 1980 to $22.3 million in FY 1983 (see Fig. 2). Five agencies provided all of the working funds for the Task Force in FY 1983. EPA's share was slightly over 50 percent of the total budget. DOI and the USDA's shares were about 15 percent apiece, and DOE and NOAA each contributed about 10 percent. Funding by research category reflects the emphasis on atmospheric processes (23 percent), terrestrial effects (20 percent), deposition monitoring (20 percent), and aquatic effects (15 percent). The budget for FY 1983 (the year reported on here) is shown in Table 1 and Figure 2.

Proposed increases for 1984 and 1985 suggest a larger share for atmospheric processes and terrestrial and aquatic effects. However, all areas of the research may receive increases. Budget authority of about $33 million including a proposed supplement of $5.5 million for an extensive lake survey is expected for FY 1984. A budget of $55.5 million is requested for FY 1985 in order to accelerate and expand the program to meet the urgent need for authoritative information on acid deposition and its effective management.

The Research Coordination Council (RCC) assists the Task Force on various technical and managerial aspects of the research. The RCC meets at least quarterly, or more often if necessary, to oversee and integrate the projects of the task groups with the overall goals of the National Program. The RCC includes the leaders of all the task groups and representatives from other participating research agencies. The National Laboratories Consortium advises and assists the Task Force in conducting the National Program.

Day to day management of the Task Force's activities is handled by the Program Coordination Office (PCO), which is managed by the Executive Director of the National Program.

The PCO serves as a focal point for managing and coordinating the National Program, and staffs Task Force activities. The office serves the full Task Force, reports to the Joint Chairs, is staffed and funded by

Table 1. National Acid Precipitation Assessment Program Funding by task group and by agency for Fiscal Year 1983.

FY 1983
($ in thousands)

		USDA				DOI			
	EPA	SE	FS	NOAA	DOE	NPS	USGS	FWS	TOTAL
A. Natural Sources				700					$ 700
B. Man-made Sources	1050				300				1350
C. Atmospheric Processes	3858			1050	274	50			5232
D. Deposition Monitoring	1145	404	145	500	666	100	1449		4409
E. Aquatic Effects	1935		210		550	148	445	75	3363
F. Terrestrial Effects	1468	946	1258		50	229	486		4437
G. Effects on Materials and Cultural Resources	410					535	50		995
H. Control Technologies*									
I. Assessments	1570				220				1790
Subtotals:		1350	1613			1062	2430	75	
TOTALS:	$11,436	2963		2250	2060		3567		$22,276

* Control Technologies figures not included in total. These funds for general development of sulfur dioxide and nitrogen oxides control hardware are appropriated under other preexisting programs. The Control Technologies Task Group coordinates these efforts with the assessment and research activities of the National Program.

member agencies, and is physically housed at the Council on Environmental Quality. The PCO prepares the Annual Report and the Operating Research Plan. Other functions of the office include responsibility for an annual program review and preparation of the interagency budget for the National Program. The office is the primary information source and liaison point for interaction with the States, private sector and environmental groups, the public, and other Nations. Thousands of documents are disseminated by the office and dozens of special presentations on the National Program are made each year by the Executive Director.

The Task Force has 10 leaders who manage task group activities for the National Program, one for each of the National Program's nine research categories and one for international activities. Each group is headed by a program manager who oversees the technical content of the research projects and works with the PCO to arrange for adequate resources and interagency cooperation. These task group leaders are responsible for detailed planning within their assigned areas.

Task Group	Coordinating Agency
A. Natural Sources	NOAA
B. Man-made Sources	DOE
C. Atmospheric Processes	NOAA
D. Deposition Monitoring	DOI
E. Aquatic Effects	EPA
F. Terrestrial Effects	USDA
G. Effects on Materials and Cultural Resources	DOI
H. Control Technologies	EPA
I. Assessments	EPA
J. International Activities	DOS

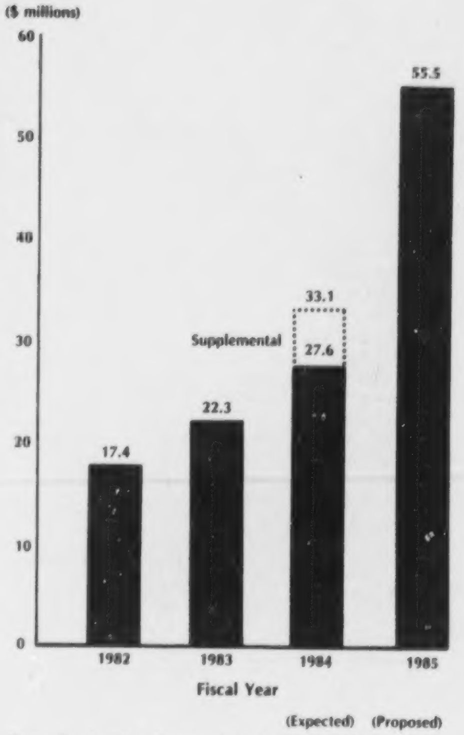
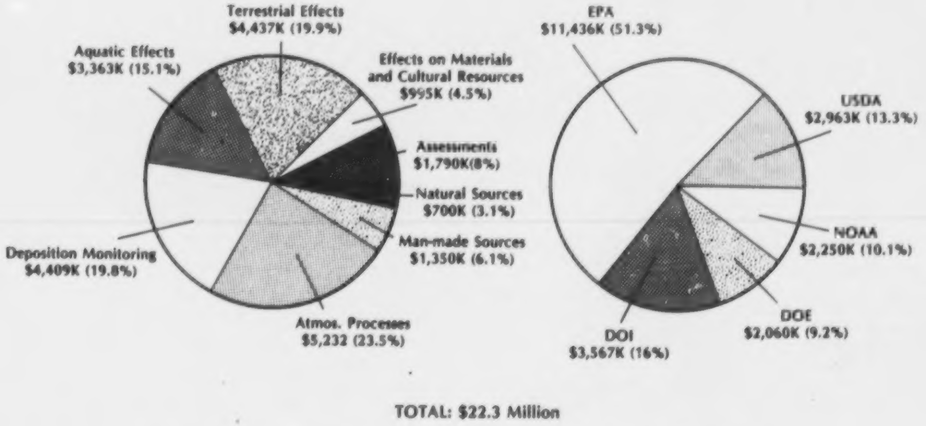


Figure 2. Funding history of the National Acid Precipitation Assessment Program



Fiscal Year 1983 funding by research category.

Fiscal year 1983 funding by agency.

Figure 3. Funding distribution of the National Program by agency and by research category for Fiscal Year 1983

The National Program is producing results at an increasing rate, rapidly disseminating them throughout the public and private sectors. As recognized in the Act, it will take a systematic effort over a number of years to adequately address all the major uncertainties about the causes, effects, and management of acid deposition.

MANAGEMENT ACTIVITIES

Research to Assist Decisionmaking

The theme for the second annual meeting of the National Program (held in January 1984) was "Research to Assist Decisionmaking." The primary purpose was to enhance the dialog between decisionmakers and the scientific community regarding the information needed by decisionmakers, the information that is available, and the information research can provide. Attention focused on the significance of current data and gaps, priorities for research, and ways to improve the communication of results to decisionmakers.

The meeting brought together the users and producers of scientific information on acid precipitation. Many different perspectives were represented: congressional staff, university researchers, industry, environmental groups, Federal agencies, and State governments. Participants were assigned to one of the following working sessions based on their expertise and affiliation: (1) Sources and Control Technology, (2) Atmospheric Processes and Deposition Monitoring, (3) Effects of Acid Precipitation, (4) Decisionmakers' Information Needs. The sessions examined the outputs and timing of planned research, the demands of decisionmaking, and the inherent limitations of scientific research. A continuing dialog between the producers and users of acid deposition information was initiated and will be maintained to help guide the National Program in assisting decisionmakers.

Peer Reviews

Examining research results and reviewing proposed and ongoing projects is an integral aspect of managing the National Program. Through the peer review process, external experts from academic institutions, the private sector, environmental organizations, States, and other Nations critically evaluate the adequacy and comprehensiveness of the National Program as well as the quality of the scientific work. The reviews focus on the relevancy and interrelationship of the various research projects to the national effort, and the application of research results to assessment purposes.

The first full review of all aquatic and terrestrial effects research was held in February 1983. The attendees included project managers, researchers, and representatives from State, private sector, and environmental groups, and others interested in the program. The objectives of the meeting were: (1) to provide a forum for review of task group plans and the contribution of individual projects toward ultimate Program goals, (2) to provide an external review of the scientific and technical approach, and (3) to facilitate exchange among scientists.

The Natural Sources, Man-made Sources, Atmospheric Processes, and Deposition Monitoring Task Groups were peer reviewed in August 1983. The review was conducted by an invited panel of distinguished scientists from academic institutions, the private sector, and State governments in the United States, and Federal and Provincial governments in Canada. Key areas addressed by the review panels included scientific quality, relevancy and timeliness of the research, and adequacy of funding.

The first cycle of the peer review process was completed with the reviews of the Assessments and the Effects on Materials and Cultural Resources (Materials Effects) Task Groups, held jointly in early February 1984.

Detailed comments from the reviews are distributed to the appropriate agency managers and researchers. The Task Force and its member agencies use the information generated by the reviews to help guide the National Program with decisions on project funding and research direction. Summary reports of the peer reviews are produced and made available to all interested parties.

Federal – State – Private Sector Coordination

In November 1982 the Task Force initiated and jointly sponsored the Acid Deposition Research Coordination Workshop. This encouraged cooperation and coordinated planning between Federal research efforts and those of State and local governments, the private sector, and environmental organizations.

The meeting participants collectively developed statements concerning the scope of the national research effort, future research needs, and plans for information distribution. The Task Force agreed to investigate increasing opportunities for State and private sector participation in the National Program. The State representatives agreed to organize by regions to identify needs, expertise, and resources. Since the workshop, National Program representatives have participated in several meetings with the States to help identify specific research needs by regions.

Planning for a follow-up meeting in the fall of 1984 to discuss progress on coordination of research is well underway. Joint sponsorship of the meeting by Federal and non-Federal groups is proposed. The workshop steering committee includes representatives from the Electric Power Research Institute, State governments, and the Federal program. The workshop will also present an update of research projects established since the first meeting and develop ways to collaborate on all phases of research.

A tangible example of joint planning and cooperation is the Working Group for Atmospheric Field Experiments. This group assures timely communication for planning and analysis purposes among the separate research programs and recommends paths to integrate and coordinate substantial field measurement programs.

The Working Group is currently evaluating plans for major field experiments to better understand the relationship between sources and deposition at specific locations. The empirical information gained will help develop efficient control strategies with the ultimate goal of providing sufficient information to assess alternative acid deposition control strategies. A large-scale field measurement program such as this is more successfully undertaken by using all available resources. Planning and feasibility studies include representatives from the National Program, the Canadian Federal and Provincial governments, and the Electric Power Research Institute.

International Cooperation

Task Force members met with their counterparts, the Canadian Research and Monitoring Coordinating Committee, in July 1983 to review ongoing bilateral projects and discuss proposals for increasing joint U.S./Canadian acid precipitation research. Twelve ongoing projects were identified, and proposals for 21 more were discussed, ranging from atmospheric modeling and monitoring to forestry effects research and data base intercomparisons. The Task Force has identified appropriate U.S. and Canadian contacts for each proposed project, and will proceed with projects contingent on final funding decisions.

Task Force members also met with representatives of the research effort in the Federal Republic of Germany (FRG) during FY 1983. There is strong mutual interest in developing cooperative research on atmospheric processes and forestry. Exchanges of U.S. and West German scientists have been arranged to visit each country's research sites and to develop plans for further cooperation. After these site visits take place in May 1984, the International Activities Task Group will serve as the mechanism for the implementation and coordination of U.S./FRG acid precipitation research cooperation.

The U.S. National Program is also working with other Nations' research efforts under the U.N. Economic Commission for Europe Convention on Long-range Transboundary Air Pollution. Plans for an international effort of standardizing methods and conducting multilateral activites are being developed for approval by the Convention's Executive Body in September 1984.

The Evolving Science of Acid Deposition

Acid deposition research has moved scientists into a particularly complex arena where new results often appear inconsistent with existing hypotheses. New hypotheses are being proposed and tested, and new data are showing that some earlier ideas about acid deposition may have been oversimplified, unrealistic, or incorrect.

This section of the Annual Report reviews some of the recent advances and uncertainties in the scientific understanding of the acid deposition phenomenon and its effects, resulting from the research sponsored by the National Program and numerous other sources of scientific information here and abroad.

NATURAL ACIDITY OF PRECIPITATION

Early estimates of the natural pH of precipitation were based solely on the equilibrium of carbon dioxide in the atmosphere with "pure" water. A pH of 5.6 was subsequently chosen as the baseline against which the seriousness of current acid precipitation levels was judged. It is now clear that other natural factors, such as organic acids, naturally-emitted sulfur and nitrogen compounds and alkaline dust, also affect precipitation's normal acidity. Any baseline pH must account for these factors and the 5.6 value is no longer appropriate.

Using pH 5.6 as a precipitation acidity baseline led to the conclusion that some areas in the eastern U.S. receive precipitation 25 times more acidic than expected in natural precipitation. More recent studies in remote parts of the world on natural sources of atmospheric acidity suggest the unpolluted pH of precipitation is closer to 5.0 than to 5.6. Those regions of the United States experiencing the most acidic annual average precipitation are now estimated to receive 6 to 7 times the average background natural acidity of remote areas.

Estimating the natural pH of precipitation remains a research issue. Comparing the present precipitation pH in the United States with that at remote locations to quantify historical change has limitations. The most notable is that the pH of precipitation is determined by many chemical substances; thus, the measures at different locations can be the same for quite different reasons. As a result, researchers are now concentrating more on quantifying precipitation chemistry as a whole than on pH alone, focusing on changes of ecological significance from both alkaline and acidic substances. Measuring substances in precipitation like sulfur, nitrogen, and calcium in both polluted and unpolluted environments will allow better estimates of historical change in precipitation chemistry and its significance.

Awareness of natural acidity and total chemistry as they influence the environment has changed our thinking not only in documenting trends in precipitation chemistry but also in the approach to both effects and atmospheric research.

RELATIONSHIP BETWEEN EMISSIONS AND DEPOSITION

When considered globally and over many years, the axiom that what goes up must come down is true as far as emissions are concerned. The uncertainty focuses on when, where, and in what form emissions are deposited on less than global spatial scales and over shorter time periods.

The relationship between emissions and deposition is complicated by atmospheric variability and chemical transformations in the atmosphere during transport. Furthermore, acidic and acidifying substances are found not only in rain or snow, but are also deposited as dry gases and particles. Wet deposition can be accurately documented, but no standardized scientific techniques yet exist to measure dry deposition, which may account for 25 to 80 percent or more of the acidity deposited in some areas. The timing, amount, and composition of this wet and dry deposition can influence the effects on the sensitive receptors.

Based on the limited information available, it is now suggested that, when averaged over the entire eastern half of North America for a year or more, there appears to be nearly a one to one (linear) relationship between sulfur dioxide emissions and sulfate deposition. This relationship does not necessarily hold true for smaller spatial scales or shorter time frames. A 50 percent reduction in sulfur dioxide emissions resulting in an overall average 50 percent reduction in wet sulfate deposition over a large area, does not guarantee a 50 percent reduction at a specific site. We are still unable to reliably predict deposition at specific sites or over sensitive regions of critical concern. This complicates designing optimized control strategies or providing strong assurances that a given reduction in emissions will result in a specified environmental benefit.

The acid deposition policy debate has focused primarily on sulfur dioxide. The role of nitrogen oxides, oxidants like ozone or hydrogen peroxide, and other factors interrelated with acid deposition is uncertain, but atmospheric and effects studies are making it clear that these other factors are also important.

Sulfates contribute about two-thirds of the acidity to precipitation in the Northeast; but, nitrates can contribute over half of the acidity in western regions of the United States. In addition, most of the acid deposition policy debate has focused on long-distance transport, even though local sources are believed to be significant in many cases. The relative role of local versus distant sources varies greatly among different receptor sites and remains a major uncertainty in evaluating the effectiveness of possible control strategies. The National Program is examining local as well as distant inputs to deposition.

Improved understanding of the complex processes of transport, transformation, and deposition is essential for the reliable assessment of the consequences of various control strategies. The route to improved understanding of these processes is to conduct research to test existing hypotheses and to develop improved tools for predicting reliably the relationships between emissions and deposition.

A number of research approaches are being pursued by the National Program and others, the main ones being laboratory studies, field studies, and mathematical modeling. Laboratory studies are improving our understanding of pollutants emitted into the atmosphere, of chemical reaction rates and mechanisms, and of the products of these reactions.

Mathematical simulation models provide a basis for integrating and interpreting the research studies on atmospheric transport, chemical and physical transformation and removal, and for quantifying source-receptor relationships. Existing models have fundamental weaknesses in that a number of phenomena have not been treated fully and the chosen parameters of the various processes have not been coupled with real-world validations. With advances in scientific research and in computer technology the field is ripe for progress.

To meet the assessment objectives of the National Program, an advanced Eulerian Regional Acid Deposition Model (RADM) is being developed. The RADM is being assembled in modular form from existing modeling components and will incorporate more realistic definitions of processes as they become available. To aid the interpretation of modeling results and the proper assessment of source-receptor relationships, efforts are focusing on statistical and uncertainty analysis. As they become available, the results of the Eulerian modeling efforts will feed into the assessment activities of the National Program. Canada is also supporting the development of a Eulerian model, and scientists in both countries are working cooperatively.

The development of other less complex models is also contributing to our improved assessment capabilities; these include models that can be used to assess the effects of nearby point or urban sources of acidic materials and precursors, and models to provide complete sulfur and nitrogen budgets for North America. Model intercomparisons are also in progress.

Theoretical models by themselves, however, cannot provide the necessary scientific credibility in determining source-receptor relationships and must be evaluated by comparing model results with actual observations. Therefore, large-scale field studies are needed to provide the data to confirm model assumptions and model characteristics. In the past, the lack of model evaluation has been a key factor in the scientific uncertainty attached to numerical models and, hence, in their limited use for assessment and policy analysis purposes.

An alternative method to numerical models for determining source-receptor relationships is empirical determination. Field experiments for this purpose will, of necessity, be large and costly; feasibility studies are now being undertaken. Technology is also being refined that will allow the improved tracking of pollutants in the atmosphere and their deposition on the earth's surface.

To insure that the various field experiments are planned and executed in a coordinated and cost-effective way, a Working Group on Atmospheric Field Experiments has been established that involves scientists working under the National Program, in the private sector, and in Canada.

AQUATIC EFFECTS

Predicting biological response to acidification depends not just on measuring acidity itself, but also upon knowing concentrations of substances like sulfate, calcium, aluminum, and organic matter. Even when acidity (pH) is equivalent between two similar lakes in the same region, observed fish populations can differ widely. Different concentrations and the interactions among the numerous substances present in the water, such as aluminum and organic matter, may be the key. Scientists believe that fish do not successfully reproduce in some clear acidic waters largely because toxic aluminum concentrations may occur as acidity increases. Such effects work slowly and rarely result in massive kills of total fish populations.

Aquatic chemists are still unable to predict reliably the rate of change in surface water chemistry that is caused by a certain rate of acid deposition. Some surface waters have been affected by acid deposition, but how many still must be determined. Hypotheses based on currently available information predict rates of surface water acidification ranging from no significant changes at present levels of acid deposition to predictions that numerous systems will become increasingly acidic in the near future. An increased awareness of the influence of soils and vegetation on surface water chemistry is largely responsible for this divergent thinking. It is not yet possible to determine which predictions are correct, and under what conditions.

Declines in pH and alkalinity (a measure of acid-neutralizing capacity) were first described in Scandinavian lakes characterized as nutrient poor, surrounded by thin (or no) soils underlain by granite, with steep slopes. From the chemical changes observed, it appeared that in such lakes acid deposition consumed the acid-neutralizing capacity of the watershed and the associated water bodies to a point at which acidification could occur. In systems with such limited acid neutralization capacity (or sufficiently acid soils) it is believed that once the neutralization capacity is reduced, surface water quality will resemble precipitation chemistry within years to decades. Surface waters with these response characteristics have been identified in a few areas in the United States, and represent one category of waters and watersheds commonly referred to as "quick response" systems (changing in time frames of years to decades).

Quick response systems represent the most sensitive class of surface waters. In contrast to these systems are "no response" systems (subject to change in time frames of centuries or millenia). Wet and dry deposition of acid and acidifying substances typically pass through the vegetation canopy and over or slowly through soils before entering water bodies. At any point along this pathway, various processes can neutralize the acidity of the precipitation. Many terrestrial systems offer sufficient neutralizing capacity to prevent the bulk of most highly acidified precipitation from entering a water body in an acidic form. In addition, runoff from agricultural activities may be expected to overwhelm natural inputs.

Between the two extreme types of surface water systems are those referred to as "delayed response" systems (subject to change in the time frames of decades to centuries). Four major processes control the rate at which these systems might be acidified:

- Acidity and amount of deposition.
- The release of base cations to the water flowing through the soil.
- Retention of sulfate by the watershed.
- Biological transformations within the terrestrial and aquatic systems.

Assuming that deposition of acidic and acidifying substances remains the same, the later three processes control the rate of acidification, and collectively could be referred to as neutralization buffering capacity. The rate at which neutralization capacity is chemically produced or consumed in the soil is controlled by the release of cations like calcium and retention of anions like sulfate; soils differ widely in their neutralization capacity. A myriad of other processes (both chemical and biological), including the hydrologic route and rate of water movement through soils may be important. Delayed response systems, found in all regions of the United States, are subject to acidification when sulfate retention has been exhausted and base cation release is less than the amount of acidity being introduced by acid deposition.

The amount of sulfate that can be retained (adsorbed) in a soil depends on the chemical composition of soil, temperature, vegetation type and growth, and soil depth. Surface water acidification can occur only after the soil's capacity to retain sulfate or other acid anions like nitrate is exceeded and these substances are able to leave the soil and enter lakes and streams.

Movement of acid anions like sulfate and nitrate from the soil to lakes and streams does not necessarily result in surface water acidification. Acid cations like hydrogen or aluminum must move with the sulfate anion for acidification to occur. If sufficient base cations such as calcium and magnesium are present, they move with the acid anions, therefore contributing little if any acidity to surface waters.

In general, there are two pools of base (acid neutralizing) cations in soils:

- Those on soil exchange sites which are adsorbed on soil particles and are readily reactive.
- Those that form soil minerals (derived from rock), and biomass which represent a large, slowly reactive reserve.

Once the input of acids exceeds the rate of release of base cations from either pool in the soil, precipitation is not completely neutralized and it proceeds to surface waters in acidic form.

In quick response systems, where sulfate retention is small and sufficiently acid soils exist, acidification usually occurs rapidly as a result of acid deposition. Lakes and streams associated with watersheds having a high ability to retain sulfate but low ability to supply base cations will acidify at slower rates. Those watersheds with a high ability to supply base cations are protected from change. The major question is the extent and location of these different type systems in the United States.

For delayed response systems, there is uncertainty concerning the rate at which soil and surface waters will respond to acid input. For example in systems where sulfate adsorption capacity is high and cation release is low, it is not certain that associated surface waters would be acidified. Theoretically, these soils could deteriorate in their ability to assimilate acid inputs. As acid inputs continue, less and less of the deposited sulfate would be retained, and the surface waters could become increasingly acidified. However, where sulfate adsorption capacity has been exceeded and associated surface waters are not now acidic, it is unclear whether these systems will acidify in years to decades. In these systems, cation release may be sufficiently rapid to renew this portion of the soil's neutralization capacity, thereby preventing further deterioriation of the surface water. In these instances, there is disagreement as to whether further acidification will be gradual over periods of centuries or perceptible in years to decades. The disagreement stems from a lack of data.

To resolve these debates, we must determine the rates of cation exchange and renewal (mineral weathering rates) and how they are affected by acid deposition, better understand the chemistry of acid sulfate adsorbing soils, and quantify the sulfate retention capacity of soils. Other variables, such as the hydrologic pathway of water through terrestrial systems, which determines the contact time between soil and precipitation and thus contributes to the potential for neutralization, must also be examined as factors contributing to the acid-neutralizing capacity of ecosystems.

All these issues are being investigated through the National Program. Making a valid assessment of how many aquatic systems will become acidic in the future depends on the results of research now in progress to define and quantify the processes involved. The assessment also requires an accurate inventory of terrestrial and aquatic ecosystems categorized by characteristics determined to be indicators of potential acidification.

TERRESTRIAL EFFECTS

Soil scientists generally believe that most managed agricultural soils are not very vulnerable with respect to acid deposition. Materials routinely added to such soils in the form of fertilizer and lime overwhelm the influence of atmospheric deposition. For unmanaged soils, recent studies on natural soil acidity production have decreased concerns over soil pH changes. The deposition of acidic substances on soils may be making only a minor contribution to the natural soil acidification processes. As noted in the previous subsection, it is now believed that understanding the previously overlooked sulfate adsorption and mineral weathering rates in soils is crucial to understanding how soils react to acid deposition. Both processes vary widely in ecosystems of North America.

The sulfur and nitrogen in acid precipitation are primary plant nutrients. Because of this, acid deposition may have both positive and negative effects on plant growth. Scientists have found little conclusive evidence for major direct effects of acid precipitation on vegetation at current deposition levels. The direct effects on crops appear less significant than those related to other air pollutants such as ozone. In studies where specific crop varieties have demonstrated sensitivity, other varieties or cultivars of the same crop were found not to be sensitive. Although future research is required to increase the certainty of our conclusions, concern over crop losses has decreased substantially.

For forests, the story is different. Initial studies and hypotheses on forest tree productivity indicated that forests were not expected to be threatened by acid deposition. The primary constituents of acid deposition, nitrogen and sulfur, are essential nutrients for optimal forest growth. Nitrogen deposition was even expected to increase production in most cases because inadequate nitrogen can limit forest growth. Indeed, in some parts of Scandinavia, forest growth apparently has increased. The balance of sulfur, on the other hand, rarely limits growth in forest ecosystems; it is believed that direct damage caused by excess sulfur is rare. However, observed declines in tree growth and forest dieback in areas with elevated pollution levels and high acid deposition, such as the eastern United States and central Europe, have heightened concern about the potential negative effects of acid deposition and other air pollutants on some forests.

Within the past few years, West German scientists have observed increasing evidence of forest damage. The forest area showing damage is expanding rapidly. A survey in 1980 indicated that 8 percent of West German forests had some trees displaying evidence of damage. A 1983 survey indicated the damage was evident in 34 percent of the forest regions. The specific causes of these observed forest changes are still being debated, but air pollutants are prime suspects. While the initial concern was about sulfur dioxide and acid deposition, many scientists currently believe nitrogen oxides and oxidants such as ozone may be contributing to the observed forest growth changes. Several causes may be acting together and many different hypotheses have been proposed in West Germany to explain the observed forest changes. Most of the affected forests in West Germany are closer to emissions sources than such areas in the United States and have higher ambient levels of polluting gases while receiving precipitation of roughly similar acidity.

Under the National Program, scientists are beginning to look more closely at forest growth history in the United States. From initial surveys of forests in the eastern United States it is becoming evident that the symptoms of decline are somewhat different than those being observed in West Germany, but apparent decline in forest tree growth over the last 20 years is measurable in a number of eastern forests. The slowing growth, as detected by tree ring analysis, indicates a broad regional phenomenon observed in several species and in both young and old trees. In some high elevation areas, visible dieback of certain coniferous tree species also has occurred and acid deposition is being investigated as one potential cause. Several hypotheses are currently proposed to explain the dieback and declines in tree growth both in West Germany and the United States:

1. Gaseous air pollutants, such as ozone, are causing damage to tree foliage and either alone, or by interacting with acid deposition, affecting tree growth.

2. Deposition of metals, alone or interactively with acid deposition, is directly or indirectly affecting tree growth.

3. Acid deposition is increasing the leaching of nutrients from the foliage of trees at a rate sufficiently rapid that uptake and recycling of lost nutrients cannot maintain adequate supplies of nutrients in the tree foliage.

4. Acid deposition is acidifying soil water, increasing aluminum concentrations, and ultimately affecting root growth and nutrient and water uptake.

5. Nitrogen saturation of forest soils is changing the beneficial relationships between trees and soil

microorganisms either directly or indirectly, resulting in nutrient and water imbalances.

All five working hypotheses appear to have some merit. Indeed, many of the factors proposed to have contributed to forest decline may be occurring simultaneously because they are not independent of each other. For example, increases in ozone, metals deposition, and acid deposition all appear to have occurred concurrently in the eastern United States. Further research is needed to determine which factors primarily cause the observed dieback and/or declines in growth. Because consideration must also be given to natural environmental stresses such as drought and pests and potential interactions with acid deposition, the issue becomes exceedingly complex.

The decline in forest tree growth in the United States began in the late 1950's and early 1960's. Climatic fluctuations alone do not presently seem to explain these declines adequately. Man-made causes are thus prime suspects. Research is underway to investigate the role of acid deposition in the observed growth changes. Among air pollutants it is unclear, however, which are of more concern. Hypotheses suggesting nitrogen oxides and ozone as the primary factors influencing forests have been proposed, while in the case of surface water impacts, sulfur is still believed to be the prime factor of interest.

Intensive study in the United States, West Germany, and elsewhere is now testing the many competing hypotheses. The potential for air-pollutant-related damage to forests is a rapidly growing concern because the economic and social consequences of forest damage could far exceed those related to surface waters. The National Program has greatly accelerated research in this area and has initiated cooperative efforts with West Germany and Canada on this important subject.

MATERIALS AND OTHER EFFECTS

Damage to materials from atmospheric deposition takes a variety of forms including the corrosion of metals, erosion and discoloration of paints, and deterioration of building stone. All of these effects occur to a significant degree as a result of natural environmental conditions. Moisture, carbon dioxide, sunlight, atmospheric oxygen, temperature fluctuations, and the action of microorganisms all contribute to the deterioration of materials. Quantifying the specific contributions of anthropogenic air pollutants to such damage is a complex task. Furthermore, distinguishing the relative amount of damage caused by specific pollutant transformation and contact processes (for example, acid precipitation) becomes even more difficult.

The percent of materials degradation that occurs from acid deposition, in contrast to the numerous other natural variables which cause degradation, is not known. The distinction between the effects of dry (including gaseous and particulate) and wet deposited substances is difficult to assess. The primary factor in degradation of materials due to acid deposition is probably the corrosive action of the acids themselves. These acids are formed from sulfur and nitrogen oxide transformation. It appears that the impact of dry deposition on moist surfaces or dry deposited materials in a very humid environment is important for understanding the effects on materials. Under these conditions, the acids can become highly concentrated, doing excessive damage.

Determining the direct effects of acid deposition on materials depends on our understanding of atmospheric corrosion, and the chemical processes of materials weathering and deterioration. Our understanding is directly related to our ability to discern through a coordinated set of laboratory and field exposure studies how sulfuric and other atmospheric acids attack materials; this includes not only direct surface corrosion, but secondary chemically induced, stress-related failure resulting from weakened mechanical strength.

The direct effects on human health of inhaling sulfate particles and aerosols continue to be studied under other pre-existing Federal programs. Studies in the National Program of acid deposition's relationship to human health focus on the new area of indirect effects after these substances are deposited. In this context, no significant indirect human health effects have yet been documented in the United States as being a consequence of the deposition of acid. The potential health impacts related to drinking water and the food chain are covered under the aquatic and terrestrial effects portions of the National Program.

The National Program's first survey of New England municipal drinking water supplies did not indicate any demonstrable effects from acid deposition. However, data on the impacts of acid deposition on drinking water quality are still scarce, with the most serious lack of data in the ground water effects area. Increasing corrosivity of acidic water is probably the most significant potential impact. Populations could be exposed to higher concentrations of corrosive toxicants if water becomes more acidic.

The complexity of the acid deposition phenomenon and its effects is such that definitive answers to many key questions are not yet available. Scientific thinking about acid deposition issues has changed and is likely to continue to change. Fortunately, given the acceleration of research under the National Program, by the private sector, States, and other Nations, major strides forward in our understanding are expected in the coming years.

Research Progress and Outlook

A. *Natural Sources*

BACKGROUND

Most acidic and alkaline compounds in the atmosphere come from natural as well as man-made sources. Biogenic sources include plant and bacterial emissions and decay products on land, in tidal and intertidal areas, and in nutrient-rich areas of the oceans. Volcanos, lightning, wildfires, and airborne particulates in ocean spray and dusts are nonbiogenic natural sources. These natural sources emit sulfur dioxide, nitrogen oxides, ammonia, organic compounds, alkaline particulates, and other critical substances, but how much is often poorly quantified. Emission rates of the compounds vary with time of the day, month, season, and place. Because their concentrations are generally extremely low, unequivocal measurements of natural source strengths are rare.

Past estimates of source strengths carry large uncertainties: Researchers have estimated natural emissions at 35 to 85 percent of the global sulfate budget. Sulfur compounds from biogenic activity probably contribute the most. Natural nitrogen emissions are thought to constitute 40 to 60 percent of the global nitrate budget, mostly from lightning and biologically active soil.

Even so, relatively small amounts of global sulfate and nitrate are deposited in North America. At most, 5 percent of the deposited sulfur is currently thought to come from natural sulfur sources. (This estimate, however, is based essentially on one data set, the validity of which is now being reexamined.) Natural nitrogen sources in North America are considered to be from 4 to 40 percent of the total emissions (see Table A-1). (These, too, are rough estimates, based on relatively few direct measurements.) Because of the preponderance of man-made sources of sulfur and nitrogen in the northeastern United States, the natural contribution to the regional total is very small.

Ammonia and alkaline dust and particulates of natural origin can act to neutralize and offset the effects of acid deposition. But, the levels of these materials in the atmosphere are not well established. Their influence on the chemistry of the deposition in North America has not been determined.

Natural sources of organic compounds play a role in producing oxidants that convert sulfur and nitrogen compounds to sulfuric and nitric acid in the atmosphere. Present estimates indicate that emissions of organic compounds from natural sources may exceed those of man-made origin. However, the full significance of natural sources of organics in forming atmospheric oxidants has not been established clearly.

RESEARCH GOALS AND ACTIVITIES

To resolve these uncertainties, the National Program's research on natural sources has set the following specific objectives:

1. Establish the reliabilities of state-of-the-art instruments and techniques for measuring sulfur fluxes.
2. Critique and use existing data bases on natural sulfur emissions to estimate the strength and temporal variations from land and ocean sources.
3. Develop instruments and techniques to measure natural nitrogen fluxes, including those of ammonia.
4. Identify the major potential sources of natural nitrogen emissions through field measurements.
5. Establish the precipitation chemistry of nitrogen and sulfur compounds of natural origin with field measurement, modeling, and laboratory studies.
6. Make an initial assessment of the natural alkaline emissions that can contribute to precipitation chemistry, develop new measurement techniques, and resurvey these emissions.

Reaching these goals will lead to a significant accomplishment by the National Program: an experimental data base that characterizes the source strengths of the natural sulfur, nitrogen, chlorine, and alkaline emissions that influence precipitation chemistry both regionally and nationally.

These findings, and similar ones from the man-made sources research, will be fed into the atmospheric transport/transformation and source-receptor models used to study atmospheric processes. The models will then be able to compare the impact of natural emissions with that of man-made emissions.

PROGRAM ACCOMPLISHMENTS—FY 1983

The major accomplishments for the Natural Sources Task Group for FY 1983 are summarized here.

Technique Development. New analytical techniques for sulfur- and nitrogen-containing species such as a fast-response chemiluminescence detector for nitric oxide have been developed and are being field-tested. Better calibration techniques and procedures have been devised for sulfur detectors at the extremely low levels needed to accurately measure dispersed sulfur emissions from soils and vegetation. New approaches, such as a gradient technique, to measure biogenic emission from soils and vegetation have yielded promising results. Preliminary laboratory studies indicate that special techniques (tungstic acid denuder tubes) offer a promising means to measure quantitatively low concentrations of ammonia.

Field Evaluation and Certification of Measurement Techniques. Validation of new measurement techniques and confidence in data obtained from techniques presently in use required a critical, continuing program of instrument intercomparison and evaluation. Two research teams involved in the National Program have collaborated in a successful laboratory intercomparison for detecting carbon bisulfide, carbonyl sulfide, and other reduced sulfur compounds. Work has indicated that the techniques that were used earlier to measure natural sulfur-compound fluxes may have significant analytical problems.

Modeling. Studies are progressing aimed at partitioning likely sources of natural nitrogen compounds. Using measurements from remote oceanic areas, photochemical models have revealed that most of the nitrogen produced over the oceans arises from lightning (see Table A-1). These calculations tentatively estimate the lightning contribution to nitrate deposition over North America at about 8 percent of the man-made (reactive) nitrogen emissions (with a current uncertainty factor of 3).

Table A–1. Acidic nitrogen sources (as nitrogen) in the United States

Natural:	(Million tons per year)
Microbial soil emissions	0.22 – 0.88
Lightning	0.08 – 0.77
Biomass burning	0.06 – 0.17
Ammonia oxidation	0 – 0.11
Stratospheric flux	< 0.05
	0.36 – 1.93
Man-made:	
Fossil fuel burning	4.64 – 6.96
Range of total emissions	5.00 – 8.89
Range of natural emissions — Percent of total emissions	4 – 40%

Field Measurements. Oceanic field measurements have determined the concentration of the reduced sulfur compounds in biologically productive waters in the Gulf of Mexico and North Pacific Ocean. In addition, preliminary evaluation of the methods used to obtain the Sulfate Regional Experiment (SURE) biogenic sulfur emission data base, the most complete one available, indicates that the SURE estimates may contain errors that caused an underestimation of sulfur emission rates.

FUTURE ACTIVITIES

Activities planned for natural sources research under the National Program continue those outlined in the 1982 Annual Report, with several new elements added in response to suggestions and comments received during the year.

A major element in the natural sources research program is determining the confidence levels of various techniques used to estimate sulfur gas emissions from natural sources. The information gained will permit a better assessment of the existing data base. During FY 1984, sulfur measurement techniques will be compared, and, if successful, these comparative techniques will be used to check previous sulfur emissions studies. These comparisons will be completed in FY 1985. After these comparisons are completed, an adjusted inventory, categorized by soil types, can be done to show the new estimates of sulfur compounds emitted to the atmosphere. This process is aimed at providing a timely 1985 Assessment of the relative importance of natural versus man-made sulfur sources in North America.

Parallel to these studies, a detailed field and laboratory investigation will examine the characteristics of specific major sulfur emitters. These latter data will provide a much-needed prognostic understanding of natural sulfur sources and their importance to the acid deposition problem by FY 1985.

Research vessels will further explore oceanic emissions of sulfur, quantifying the factors that influence the rate of fixation of inorganic sulfur by marine organisms, the release and subsequent vertical distribution of reduced sulfur compounds within the surface zones, and the transport of these compounds across the ocean/atmosphere interface. Additionally, sulfur compounds in productive seawaters will be correlated with biological parameters using remote sensing techniques. Sulfur concentrations in seawater and in the atmosphere above the ocean will be measured simultaneously to determine fluxes of the compounds from the ocean.

Instrumentation to determine nitric oxide fluxes from the soil will be assembled into a portable field laboratory during FY 1984 and FY 1985. This laboratory will evaluate gradient and box techniques for flux measurement during FY 1985. The fluxes from representative soil types will be measured in FY 1985 and FY 1986.

A new technique will be field tested in 1984 and 1985 for determining total nitrate budgets in the atmosphere, permitting an assessment of natural sources of nitrate into the atmosphere during FY 1985 and FY 1986. Special (denuder tube) techniques for detecting ammonia will be tested in the laboratory during FY 1984. If successful, field testing of the instrumentation will begin during FY 1985.

Modeling the distribution and deposition fluxes of nitrate, sulfate, and ammonium from natural sources will continue. These models will use measurements of nitrate deposition in remote regions of the earth to deduce fluxes and deposition rates. It is anticipated that these studies will find previously unsuspected sources, if they exist. An initial global budget of atmospheric nitrate precursors will be presented in FY 1985. Models will calculate natural organic compounds' role in forming organic acids such as aldehydes and carboxylic acids; the results will be compared to materials in sampled air and precipitation in rural and remote areas. The role of oxidants produced from natural hydrocarbons in transforming precursors into sulfuric and nitric acids also will be studied.

Laboratory kinetics studies will investigate the paths by which natural emissions are converted to acids so that atmospheric models can later assess the acidification of precipitation by natural emissions.

A preliminary estimate of the resuspension of alkaline dust in the continental atmosphere will be done in FY 1984. Ammonia estimates will be underway by FY 1985. This research should increase our understanding of the role played by acid-neutralizing species in the atmosphere.

INTERRELATIONSHIPS

In the broad area of atmospheric research, considerable work is being done that is highly relevant to the work of the Natural Sources Task Group. Outside research is not a minor addition; in some areas it predominates. Strong coordination between this research and the National Program is vital.

Investigators on the Natural Sources Task Group's projects are often the principal investigators on related projects sponsored by the National Science Foundation (NSF), National Aeronautics and Space Administration (NASA) and others. Such links to the Task Force allow rapid sharing of research information. This open dialog between the investigators promotes sharing of the results from related projects such as instrument intercomparisons (NASA), measurement of nitrogen compounds in the unpolluted troposphere (NSF), isotopic composition of wet acid deposition (U.S. Geological Survey), and ammonia emissions (NASA).

All of the National Program's research on natural sources is funded by the National Oceanic and Atmospheric Administration (NOAA). In FY 1983, about half (based on funding) of the research is being conducted in-house at three of NOAA's Environmental Research Laboratories. The remainder is NOAA-sponsored research at three universities, with NOAA personnel serving as project officers. Thus, ample mechanisms exist to closely coordinate the research within the Natural Sources Task Group. The natural sources data provided by this task group, with analogous information from the Man-made Sources Task Group, will be used by the Atmospheric Processes Task Group as basic information in the atmospheric transport, transformation, and source-receptor predictions.

B. *Man-made Sources*

BACKGROUND

Research on acid deposition has identified several pollutants linked to the formation of acid compounds in the atmosphere. Those currently believed to be important include sulfur dioxide, nitrogen oxides, volatile organic compounds, primary sulfates, ammonia, hydrochloric and hydrofluoric acids, and alkaline dusts. Sulfur dioxide and nitrogen oxides have long been recognized as major influences on acid deposition; the role of the other pollutants is under investigation.

Constructing a data base that will show the present and anticipated emissions patterns of these pollutant species and identify their sources is an important step in determining how acid compounds are formed and deposited and how these patterns might be altered. Data base accuracy must support the stringent atmospheric modeling and policy assessment requirements of the National Program.

Traditionally, creating such data bases relies primarily on estimates; wholesale measurement of actual emissions would be prohibitively expensive. Emissions factors derived from limited tests are generally used. Calculated fuel and feedstock consumption is used to estimate emissions for major point sources and large areas. Although statistical estimation improves the accuracy of national and annual emissions data, attaining reasonable accuracy for highly resolute and short time segments is significantly more difficult. Satisfactory accuracy for the National Program's data base may require new techniques.

Preliminary work has been started by the Man-made Sources Task Group to produce initial estimates of historical emissions levels from 1900 to 1980, in 5-year increments, and a detailed estimate of 1980 emissions levels. The data from both of these studies will be reviewed and refined before release. The Man-made Sources Task Group is working on a set of models to produce estimates of future emission levels. The initial version of this model set will be available in the near future.

In the post-World War II period emissions of both sulfur dioxide and nitrogen oxides generally increased until the mid 1970's, when pollution controls mandated by the Clean Air Act reduced sulfur dioxide emissions. Emissions of nitrogen oxides have continued to increase throughout the period along with increases in total fuel consumption.

Preliminary 1980 emissions estimates compiled by the National Program are presented in Table B-1. This inventory demonstrates that electric utilities are by far the largest source of sulfur dioxide in the United States, followed by other forms of industrial combustion. Although metal smelters are not a major source nationally, they are important on a local level. The table also indicates that the largest single source of nitrogen oxide emissions is transportation-related activity, followed by electric generation and other industrial combustion. The other section represented in Table B-1 includes other industrial processes and residential and commercial fuel use.

The Man-made Sources Task Group is assembling a set of computer models for alternative energy/economic forecasts and different control scenarios. Projections of future sulfur dioxide and nitrogen oxides emissions are subject to considerable uncertainties. Assumptions made about the rate and pattern of economic growth, the rates of industrial facility modernization and retirement, future technological advances, and new control regulations can significantly affect estimated future emissions. These uncertainties must be remembered when using projections from emissions models, and long-term emissions projections need to include careful uncertainty analyses. The model set will be able to account for these uncertainties.

Preliminary estimates of future emissions levels were produced by a Work Group under the United States-Canada Memorandum of Intent on Transboundary Air Pollution. More recent estimates, based on the National Energy Plan IV (NEP IV), have been compiled outside the National Program.

Estimates made by the Work Group project a gradual rise in sulfur dioxide emissions through the year 2000. In the area of highest concern over acid deposition — the 18-State northeastern quadrant of the United States — the trend of these emissions is generally estimated to remain constant or decline slightly through the year

2000, then decrease significantly between 2000 and 2030 as older, existing sources are replaced by more stringently controlled new sources. The rate and time at which this decline will occur, however, is subject to considerable uncertainty arising from factors already cited.

In general, recent sulfur dioxide emissions forecasts based on the NEP IV tend to agree with the preliminary work group forecasts, although sector-specific forecasts are slightly different, largely because of differences in economic forecasts and the other variables previously noted.

Both the Work Group and the NEP IV estimates forecast that future emissions of nitrogen oxides will increase across the country (by about 25 percent by 2000) with increased fuel use. Emissions are likely to continue to increase beyond the year 2000 unless regulations governing nitrogen oxides are enacted and control technologies for nitrogen oxide reduction become more widely available.

Experiments are underway to refine known emission factors and to develop factors for pollutants recently identified as potential precursors of acid deposition. These factors, used to calculate emissions from each source category, are typically expressed as pounds of pollutant emitted per unit of a good produced or fuel consumed. The factors are applied to production or energy consumption levels to calculate overall pollutant emissions. Their accuracy is critical in ensuring the accuracy of 1980 and 1984 emissions data bases.

Accuracy in making emissions estimates and future projections depends largely on assumptions about economic activity in industry and regulatory requirements. If the economy prompts unexpected retirement of older industrial facilities in the United States and replacement with new facilities that are subject to more stringent emissions controls, emissions forecasts could radically change.

RESEARCH GOALS AND ACTIVITIES

The fundamental purpose of the National Program's man-made sources research is to provide other task groups with information on man-made pollutants needed for the overall assessment program. This research involves developing estimates of past, present, and future emissions of pollutants from man-made sources and then devising quantitative methods to estimate the effects and costs of possible changes in government regulation of these emissions. The overall goals of this research effort can be summarized in the following objectives:

Table B–1. National emissions estimates in the National Program's 1980 Emissions Inventory* (Millions of Tons)

	Sulfur Dioxide	Nitrogen Oxides
Utilities	18.6	8.0
Industrial Combustion	4.6	3.0
Smelters	1.2	—
Transportation	0.8	8.7
Other	2.4	3.1
TOTAL	27.6	22.8

*NOTE: Task Group B is reviewing the data in its 1980 Emissions Data Base, and will release the final version of this data in 1984. The data represented in Table B-1 have undergone a preliminary review for inconsistencies; these inconsistencies are being corrected. Until the final version of the emissions data base is released, these emissions should be used with caution.

1. Compile a data base of pertinent emissions from man-made sources that is complete and accurate enough on a geographic, economic, and temporal basis to help solve the scientific questions related to the atmospheric transport and transformation of pollutants related to acid deposition.

2. Provide models that (a) predict how these emissions may be altered by such factors as economic growth, fuel supply, emissions regulation, and control techniques; and (b) calculate the cost of alternative control strategies.

The Emissions Data Base will have two components — the 1980 and 1984 versions.

The 1980 Emissions Data Base will provide emissions data for 20 km grids for the 14 northeastern States included in the Northeast Corridor Regional Oxidant Study and at the county level for some other States. Emissions are forecast on an annual level; algorithms can be provided to allocate the emissions to shorter time periods. The data base will contain detailed information on all emitting sectors. The data base will be used in the 1985 Assessment.

The 1984 Emissions Data Base will also contain emissions information at a 20 km grid level but for the 48 contiguous States and southeastern Canada. This version of the Emissions Data Base will incorporate refined spatial and temporal resolution factors and is designed to meet the most detailed needs of modelers, atmospheric scientists, and policy analysts.

Table B-2 presents the pollutants that will be included in each version of the Emissions Data Base.

The Man-made Sources Task Group will prepare three versions of the model set, one each for the 1985, 1987, and 1989 Assessments. Each version will build on previous work and be successively more complete and detailed.

A single energy/economic projection module will control the Emissions Projections Module of the model set. The detailed sector-specific models will use projections from this energy/economic module to estimate future emissions. The sector-specific models will also be able to estimate potential emissions reductions and associated costs for alternative control strategies.

The model set will also contain a module to aggregate results from each of the sector-specific models into a single report. Sector-specific models will include electric utilities, industrial combustion, industrial processes, residential and commercial fuel use, and transportation. Other sector models will be developed as needed.

To provide required information, simplified versions of planned models or generalized, multisector models will be used to fill gaps until the complete model set is available.

PROGRAM ACCOMPLISHMENTS— FY 1983

During FY 1983 several major research objectives were met that will enable the Man-made Sources Task Group to provide required information to other groups in the National Program. Each of these projects will undergo continuing review and, when necessary, revision in order to provide the most accurate information possible to the National Program. Program accomplishments are grouped into Emissions Data Base- and Model Set-related activities.

Emissions Data Base

1980 Acid Deposition Emissions Data Base. A preliminary version of the 1980 Emissions Data Base was completed during FY 1983. At this time, the data base contains information on emissions of sulfur dioxide, nitrogen oxides, total volatile organic compounds, and particulate matter from all man-made sources during 1980. The data base contains information on annual emissions for point and area sources at the county level and has been checked to ensure that there are no coding or other mechanical errors in the data. This draft version of the data base has been delivered to the Atmospheric Processes Task Group, which is using the data to evaluate earlier work done with Lagrangian atmospheric transport and transformation models. The results of the tests with the Lagrangian models will, in turn, be used to help check the accuracy of the data base.

Table B-2. Pollutants included in the Man-made Emissions Data Base.

	1980	1984
Sulfur Dioxide (SO_2)	YES	YES
Primary Sulfate	YES	YES
(H_2SO_4 fraction separated)	NO	YES
Nitrogen Oxides (NO_x)	YES	YES
Nitrogen Dioxide (NO_2), Nitrogen Oxide (NO)	NO	YES
Volatile Organic Compounds (VOC)		
Total	YES	YES
by Reactivity Class*	YES	YES
Particulate Matter	YES	YES
by Size	NO	NO
Ammonia	YES	YES
Alkaline Dust	NO	YES
Hydrocholoric Acid	YES	YES
Hydroflouric Acid	YES	YES

*Seven reactivity classes are included in this data base to provide consistency with emissions data generated by the Northeast Region Oxidant Study. Data on VOC by reactivity classes will be provided for gridded areas only.

Acid Deposition Historical Emissions Data Base. Work on a Historical Emissions Data Base has been initiated. This data base will contain estimates of emissions of sulfur dioxide and nitrogen oxides from all man-made sources at the State level. Emissions estimates in this data base will go back, in 5-year increments, to 1900. The information in this data base is being used by each of the effects task groups to estimate historical damage patterns. In particular, this information will be used by the Effects on Materials Task Group to support studies of the impact of acid deposition on monuments.

Emissions Factor Testing. An important component in developing the emissions data base is the use of detailed emissions factors, especially for fossil fuel combustion. Work begun in FY 1983 in this area will result in measurements of hydrochloric acid (from coal combustion) and sulfate (from oil combustion) emissions from commercial and light industrial boilers. Work completed this year has included the development of a detailed testing protocol for use with test equipment at the Pittsburgh Energy Technology Center. These test protocols have been carefully reviewed by the task group and should ensure that the results of these tests can be used to improve the accuracy of the emissions data base. Specifically, this work will improve emissions estimates for those sectors that may be important local contributors to acid deposition. In addition, preliminary results of this study will be used to help determine the accuracy of information in the Emissions Data Base.

Acid Precipitation Precursor Study. This study, which used detailed fuel use data to estimate emissions of pollutants related to acid deposition in the Northeast, was completed in FY 1983 and is undergoing internal Department of Energy (DOE) review. Results of this study will be used to help determine the accuracy of information in the Emissions Data Base.

Advanced Utility Simulation Model (AUSM). When completed, this model will allow the Assessments Task Group to evaluate national and regional costs and changes in emissions that would result from a wide range of control strategies for electric utilities. In FY 1983, an initial State-level version AUSM was assembled and transferred to the Environmental Protection Agency's (EPA) computing facility at Research Triangle Park, N. C. Test runs were performed to demonstrate the transferability of the model to alternate computing systems. Results of test runs for West Virginia were presented to a potential users' group at the end of the fiscal year. Further review and documentation is underway. Work has begun on developing a national-level AUSM that will include refinement of the algorithms and associated data bases in the model. External review and release of the model will be accomplished in the future.

Industrial Combustion Emissions (ICE) Model. During FY 1983, the Man-made Sources Task Group's major effort explored methods that will apply the ICE to fuel choices made for industrial combustors. Additional effort went into completing a design that will enable the ICE to estimate emissions of sulfur dioxide, sulfates, and nitrogen oxides for industrial processes as well as industrial combustion.

FUTURE ACTIVITIES

Emissions Data Base

Primary emphasis in the coming year will be on completing the 1980 Emissions Data Base, beginning the design of the 1984 Emissions Data Base, and improving accuracy.

1980 Emissions Data Base. Work to complete the 1980 Emissions Data Base will entail obtaining appropriate emission factors for pollutants not in the interim version of the data base and using these factors to develop emissions estimates. Both the emissions factors and the final emissions estimates in the data base will be carefully reviewed before this information is released.

1984 Emissions Data Base. The initial design for the 1984 Emissions Data Base will be produced during FY 1984, based on the work completed for the 1980 Emissions Data Base. The 1984 Emissions Data Base (over the 1980 version) will increase the accuracy of emissions factors and refine spatial and temporal allocation factors (see Table B-2).

Accuracy. To improve the accuracy of the data base, a project undertaken at the Brookhaven National Laboratory will examine methods to estimate the precision of the information in the data base. A 2-day workshop involving experts from within and outside the National Program will focus on methods to improve and control the accuracy of emissions data bases.

All of this work is designed to build on existing information to provide the most reliable information possible to researchers in the Atmospheric Processes Task Group.

Model Set

Man-made Sources modeling work will determine how the several emissions forecasting models will be jointly operated in the future. The task group will obtain an economic forecasting model as basic input to each of the models and set guidelines for generating baseline and control scenario forecasts. Also in FY 1984, work on the individual sector-specific models will continue.

In addition to completing the final model set required by the National Program in 1988, emissions forecasts will be made for the interim assessment currently scheduled for 1985. The task group intends to meet these requirements by either adopting simplified versions of models currently under development or using existing multisector models in the interim. The components of the model set are:

Economic/Energy Forecast Driver. An initial version will be assembled, tested, and interfaced with the existing sector-specific emissions models. Runs are planned for a baseline test mode, and further development will continue.

Advanced Utility Simulation Model. During FY 1984, an initial version of the national-level AUSM will be completed, transferred to government computing facilities, and tested. A third party validation process will be initiated for this model and all Man-made Sources Task Group models to evaluate their suitability with regard to input and output capability, the acceptability of their initial data base, the reasonableness of their projected growth and cost algorithms, and their operability. Preliminary analyses using it will be conducted with the Assessments Task Group to ensure that this model operates as designed. Final work will be completed on determining the input to the model which will be used for the National Program's analyses, and final modifications to the model's code will begin.

Industrial Combustion Emissions Model. Work on the ICE in FY 1984 will focus on delivery of a model capable of forecasting emissions of sulfur dioxide, sulfates, and nitrogen oxides at a State level. When completed, this model will estimate emissions from industrial sources of these pollutants.

Other Sector-Specific Models. During FY 1984, work will begin on obtaining emissions forecasting models for the transportation and residential/commercial sectors. The necessary components and possible structure of an Industrial VOC (volatile organic compounds) Emissions Model will be defined. The National Program will use these projects, when completed, as a comprehensive set of analysis models to help evaluate potential acid deposition control strategies.

Supplementary Studies. To better obtain information for use in these models, the task group will undertake two special studies in FY 1984. The first of these will analyze factors that may contribute to decisions to retire old facilities and replace them with new facilities (this study was initiated in FY 1983). Since older facilities are subject to much less stringent emissions control regulations, such decisions are critical to emissions trends. A second study will examine the potential market penetration of new energy-related technologies, including those for emission control.

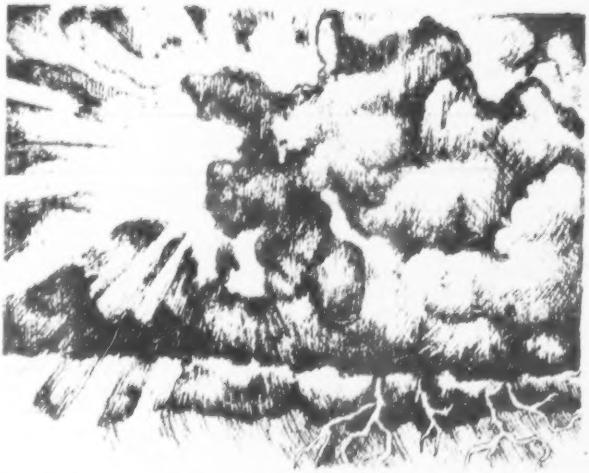
INTERRELATIONSHIPS

Much of the work program of the Man-made Sources Task Group is dictated by the requirements of other task groups. The focal point for management has been developing detailed specifications for both the Emissions Data Base and the Model Set. In particular, the detailed requirements of the Emissions Data Base are largely determined by the needs of the Atmospheric Processes Task Group. As this group refines its needs, the components of the Emissions Data Base may be revised. For example, a determination that the Task Force will participate in large-scale tracer studies may require emissions estimates applicable to specific periods of time.

Another major influence on the Man-made Sources Task Group program will be changes in air quality control regulations affecting possible control scenarios which the sector-specific models must be able to reflect.

C. *Atmospheric Processes*

BACKGROUND



A strong body of circumstantial evidence links the emissions of sulfur dioxide and nitrogen oxides with acid deposition. Regions of highest emissions appear to have the highest deposition of acidifying substances.

Once injected into the atmosphere, pollutants can undergo complex transformations, and can be transported into the higher atmosphere and over long distances by wind currents. Some pollutants, especially sulfur dioxide and nitrogen oxides, are later deposited on the surface of the earth as particles or gases. Some of these deposits are acidic. Sulfur dioxide and nitrogen oxides can react in the atmosphere to form sulfuric and nitric acids. Other compounds, such as ozone, hydrogen peroxide, and volatile organic compounds, can participate in the transformation process (see Table C-1).

To date, the complex nature of air movement and chemical transformations and the difficulty of "fingerprinting" specific sources of sulfur dioxide have made predicting benefits from source controls a difficult task for scientists.

The atmospheric processes governing the fate of emitted acid precursor pollutants include transport, transformation, and deposition.

Transport. The horizontal and vertical transport and dispersion of airborne pollutants is controlled by the wind speed, wind direction, and atmospheric stability along the path of the transported pollutant. Pollutants move downwind during well-mixed, unstable, daytime conditions (see Fig. C-1), and overnight they are frequently trapped in stable layers and drift with the varying winds at different levels. Large-scale weather patterns also strongly influence the movement and dilution of pollutants.

Transformation. While pollutants are being moved by the air currents, chemical transformations can occur. For example, the primary precursors to acid materials, namely sulfur dioxide and nitrogen oxides, are transformed at least partially in the atmosphere to sulfuric and nitric acid. The complex interactions occurring both within and outside of clouds are not yet well understood, but are known to be important elements in explaining acid deposition amounts and patterns.

Deposition. After the pollutant material is transported and possibly chemically transformed, all or most of it is ultimately deposited either by contacting a surface directly (dry deposition) or by being incorporated into precipitation and brought down to the earth's surface in rain, snow, or other forms of precipitation. Wet deposition can occur either by raindrop formation around pollutant nuclei or by collision between falling precipitation and pollutant particles or gases. The relative contribution of wet versus dry acid deposition is one of the more difficult topics being studied by the Atmospheric Processes Task Group.

RESEARCH GOALS AND ACTIVITIES

The National Program's research on the atmospheric link between precursor pollutants and acid deposition seeks to understand the processes at work and to develop improved tools for predicting deposition. The folowing are the key questions addressed by the Task Group.

1. What are the important chemical species and processes governing the formation of acidic substances in the atmosphere, and how do they operate?

2. What are the most important meteorological processes governing the transport of acidic substances and their precursors?

3. How do the processes of wet and dry removal operate and how does their relative importance change with distance from the source?

4. How can the processes of transport, transformation, and removal be modeled so that we can understand current and predict future deposition patterns?

The answers will tell us which atmospheric pollutants will have to be controlled to reduce acid deposition and which source regions are most likely to affect a specific receptor region. The models, however, can be the primary policy development tools, estimating how changes in existing pollution sources affect patterns of acid deposition. They can suggest what regions the pollution sources have affected, whether changes in emissions are needed, and in what quantities.

The atmospheric processes research is guided by the following specific objectives:

- Improve understanding of the vertical and horizontal transport of acidic substances and their precursors.
- Improve understanding of the major chemical transformations that produce acidic substances in the atmosphere.
- Improve understanding of precipitation scavenging processes in the atmosphere.
- Improve understanding of dry deposition of acidifying substances to various surfaces and under diverse atmospheric conditions.
- Improve and develop predictive and interpretive models that explain source-receptor relationships in the atmosphere.
- Perform field studies that can provide both a data base for developing and testing mathematical source-receptor models and an independent method of evaluating theoretical source-receptor relationships with field evidence.

PROGRAM ACCOMPLISHMENTS—FY 1983

Transport. Experimental field studies of vertical transport and chemical transformation in clouds are underway. Preliminary field experiments and theoretical studies have supported the hypothesis that cumulus clouds play an important role in acid transport and transformation from late spring to early fall. A set of experiments in the summer of 1984 will quantify and describe how cumulus clouds affect vertical exchange and transformations between the mixed layer and the overlying clouds.

Table C–1. Characteristics of long-range and local air pollution

Pollutant or Effect	Long-range	Local
Sulfur Oxides	Sulfur dioxide tends to be oxidized to particulate sulfates.	Exist primarily as sulfur dioxide; however, under light winds and stable atmospheric conditions conversion to particulate sulfate can occur.
Nitrogen Oxides	Significant conversion to particulate nitrates.	Exist primarily as nitrogen oxide and nitrogen dioxide, but under low wind speed, stable conditions and sunlight, conversion to organic or inorganic nitrates in particulate form is possible.
Particulate Matter (includes aerosols)	Only the smallest primary particle sizes persist. Large component of material converted from gases and vapors to particulate form such as sulfates.	Exists in wide range of sizes. Particles are capable of producing surface soiling and the formation of corrosion layers (e.g., black crust on stone).
Ozone and Other Oxidants	Ozone and other oxidants are produced from hydrocarbons and nitrogen oxides over moderate to long-range transport in presence of sunlight.	Ozone and other oxidants are likely only under low winds, strong sunlight and otherwise ideal conditions.
Dry Acid Deposition	Dry deposition of acidic particles (for example, sulfates) is possible.	Dry deposition of acidic particles is possible, especially under stable conditions, often enhanced by moist surfaces.
Acid Rain	Acid rain mechanisms may be predominantly through droplet condensation around acidic particles.	Acid rain formation may be predominantly through rain washout of acidic particles and pollutant gases.
Acid Fog (includes liquid aerosols)	Acid fog may be formed by drop condensation around acidic particles or other acidic nuclei.	Same as for long-range.

Accurate long distance tracking of pollutants vented out of the mixed layer by convective clouds may now be possible. An airborne, two wavelength lidar (luminescent) technique has been successfully developed that can locate a cloud of nontoxic fluorescent dye particles. Another technique using a perflourocarbon tracer was tested and demonstrated in experiments conducted in association with the recent Cross Appalachian Tracer Experiment (CAPTEX). Perflourocarbon tracers were released from Dayton, Ohio, and Sudbury, Ontario. The cloud was tracked at altitudes above the mixed layer to simulate the long distance transport of mixed layer pollutants vented out of and above the mixed layer by convective cloud activity (see Fig. C-2). The experiments served to demonstrate and refine the tracer technology and to provide a data base for describing and evaluating atmospheric transport and diffusion modules in regional air quality models.

Significant progress has been made during 1983 in developing a precipitation scavenging module for acid deposition modeling. The protocols of the scavenging module development for the Regional Acid Deposition Model (RADM) have been defined. In the area of field studies and data interpretation, the Oxidation and Scavenging Characteristics of April Rains (OSCAR) experimental design and operations report was completed. Four events were studied under OSCAR to look at frontal storm systems. In one of these, three conclusions were reached: (1) Calculated ionic concentrations in precipitation agreed well with actual observations; (2) most of the reactive scavenging occurred in the underlying cold air mass; and (3) approximately two-thirds of the precipitation sulfate resulted from aqueous-phase oxidation of sulfur dioxide.

Researchers have increasingly used data from existing precipitation chemistry networks for analyzing precipitation chemistry samples and reporting results during FY 1983. Data from the Precipitation Chemistry Network are helping identify atmospheric processes leading to the formation of acid precipitation. A report on precipitation chemistry spatial distribution data sets is the first attempt to merge the Canadian and United States precipitation chemistry data sets.

Attempts to approximate the long-range atmospheric transport of materials to remote sampling sites used back-trajectory climatology to study air flow patterns in American Samoa, Alaska, and Bermuda. Preliminary results indicate that Samoan rain is affected by dust from Australia and that sources of man-made pollutants observed in Alaskan ambient air may be Japan and the Soviet Union. In the Bermuda study, it was found that months with the greatest number of trajectories originating over North America also had the most acid deposition.

Transformation. A study to develop chemical transformation modules for use in the RADM is evaluating data on gas- and aqueous-phase reactions important to acid deposition. A first-generation chemical module for use in the regional model will be available in early FY 1985.

Laboratory studies now begun will clarify aqueous-phase chemical transformation processes that produce acidic substances in the atmosphere, especially hydrogen peroxide, which is thought to be the major oxidizer of sulfur dioxide within clouds. A related study will analyze rainwater to determine what fraction of the dissolved sulfate was produced through reactions involving hydrogen peroxide. The results from these

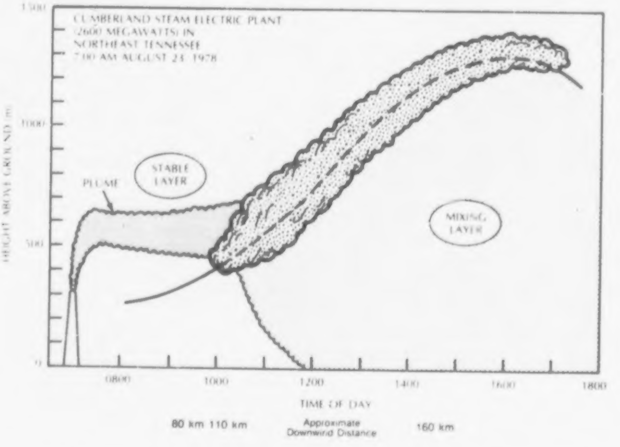


Figure C-1. Movement of a plume from a tall stack on a typical summer day.

studies will be used to construct a second-generation chemical module for the RADM.

Researchers are developing instrumentation for use in laboratory and field studies of atmospheric acidification processes. Current efforts are developing a technique for measuring gas-phase hydrogen peroxide. No reliable measurement method for this important species yet exists.

A small portable calibration system using a nitric acid permeation tube was built to field test the nylon filter commonly used to collect gas-phase acids. The calibration tests of the nylon filter indicate measurements truly indicate nitric acid loading.

Deposition. Significant progress has been made to develop deposition velocity maps of acidifying substances in eastern North America from field and theoretical investigations. During FY 1983, four dry deposition field measurement programs were conducted in conjunction with the Deposition Monitoring Task Group. These measurement programs provided data bases needed to develop and refine formulas to compute the rate at which various pollutants are deposited on the surface. Progress to date includes refinements in the matrices of deposition velocity values for gaseous and particulate sulfur. These formulas will be developed into a module for the RADM.

Model Development and Evaluation. A major goal of the National Program's atmospheric processes research is to develop mathematical simulation models that can be reliably used in predictive and interpretive modes to demonstrate source-receptor relationships. At present, highly parameterized models exist that account for the gross features of pollutant transport, transformation, and deposition. The major emphasis in the past few years has been on studying transport processes, with only rough approximations included in the models for transformation and deposition processes. Current efforts are directed toward incorporating more realistic definitions (as they become available) of all three processes into future, more sophisticated models.

A comprehensive review of regional acid deposition processes was completed for the Environmental Protection Agency (EPA) by the National Center for Atmospheric Research (NCAR). In particular, an Eulerian

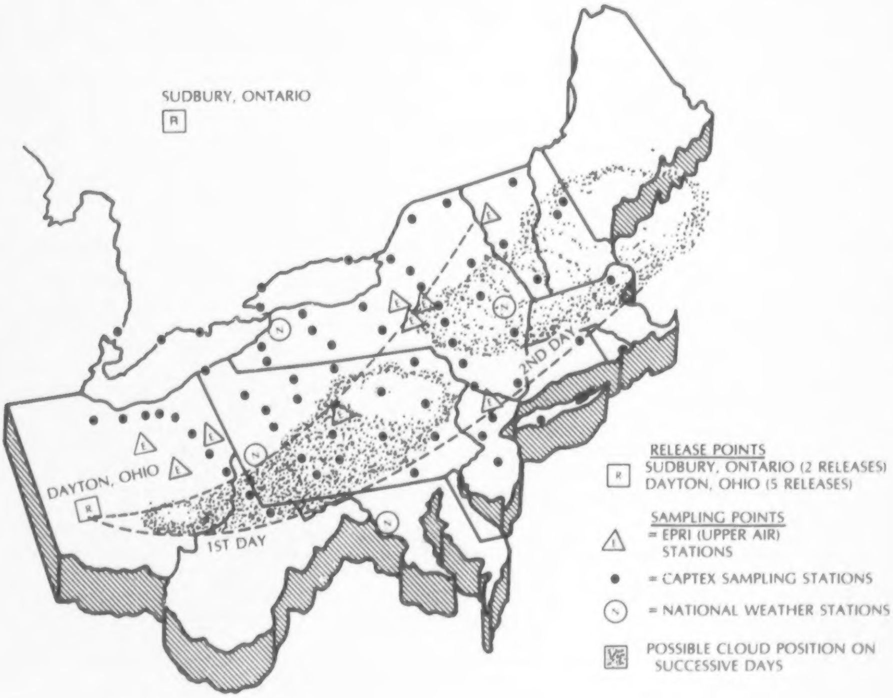

SUDBURY, ONTARIO
R
DAYTON, OHIO
R
1ST DAY
2ND DAY
RELEASE POINTS
R SUDBURY, ONTARIO (2 RELEASES)
DAYTON, OHIO (5 RELEASES)
SAMPLING POINTS
= EPRI (UPPER AIR) STATIONS
= CAPTEX SAMPLING STATIONS
= NATIONAL WEATHER STATIONS
POSSIBLE CLOUD POSITION ON SUCCESSIVE DAYS

Figure C-2. Cross Appalachian Tracer Experiment (CAPTEX): Designed to track air movement across the Northeast by repetitive release of an inert tracer.

modeling approach was recommended as most promising for incorporating more realistic definitions of all significant physical and chemical processes involved in source-receptor relationships, providing self-consistent tools for analyzing field data and evaluating alternative control options.

In FY 1983, NCAR began constructing an Eulerian RADM, which will be assembled from existing modeling components and should be ready in a preliminary form in early 1985. The major strengths of the NCAR approach will be in determining atmospheric pathways and delineating important processes.

In a companion program, a simple, easily used model will provide information about the meteorological potential for materials damage given a specified emissions inventory. Concentrations of potentially damaging pollutants will be available for a metropolitan area under a selection of meteorological conditions, thus facilitating assessment of materials damage potential.

The Eastern North American Model of Air Pollution (ENAMAP) was applied during 1983 to ascertain the changes in annual statewide wet depositions from variations in sulfur dioxide. Model results were generated to quantify wet deposition in each State as a function of the sulfur dioxide/sulfate transformation rate.

The Advanced Statistical Trajectory Regional Air Pollution (ASTRAP) Model was used during 1983 to evaluate statewide, time-varying differences in wet and dry deposition of sulfur for 1980 and 1981. Results showed that although the monthly deposition patterns varied, sometimes widely, from year to year, the annual deposition patterns for the 2 years did not significantly differ.

The Sulfur Transport Eulerian Model (STEM) simulated a 1-week period of July 1974 for the eastern United States. The simulation showed an average gas phase conversion rate of sulfur dioxide to sulfate of about 0.5 percent per hour. No in-cloud conversion processes were used in the simulation. Air concentrations and dry deposition rates were calculated. The chemistry, transport, and numerical diffusion portions of STEM-II were evaluated during 1983.

Field Studies. The development of complex mathematical simulation models understandably reflects the complexity of the atmospheric processes themselves. For this reason, the reliability of newly-developed models must be evaluated with actual measurement data. An alternative method to modeling for assessing source-receptor relationships is the empirical determination. To address both the empirical approach and the need for model evaluation data, field experiments are being conducted with tracers which are released into the atmosphere and then tracked while they are transported and diffused.

A program to study the local urban contribution to regional concentrations of acid rain precursors began in FY 1983. This program will examine the contribution from urban and industrial emissions to the chemical composition of rainfall measured downwind of Philadelphia.

Experimental field studies in summer 1983 of vertical transport and chemical transformation by nonprecipitating cumulus activity showed that pollutants from the boundary layer are entrained during the day into the nonprecipitating cumulus cloud layer. They are then either transported back to the ground or to higher elevations. Towering cumulus clouds appear to be responsible for transporting pollutants into the upper atmosphere.

Polluted air from industrialized areas sensed at Whiteface Mountain, N.Y., that showed an increase in the small particle population suggests that some of the acidity of both polluted and unpolluted clouds may be associated with natural anions, possibly organic, which are not usually analyzed. Analysis of cloud and rainwater samples collected during the summer 1982 field project showed that the oxalate anion was present. As was the case with the sulfate and nitrate ions, the concentration of oxalates was greatest at the onset of a cloud episode, after the air mass had passed over a polluted area.

One study showed that changes in physical and chemical properties of clouds by man-made pollutants inadvertently change the radiative-optical properties of clouds. Radiative-optical properties of polluted and nonpolluted clouds were calculated, applying the matrix-operator method to measure cloud-drop spectra. This could affect the climatological-mean surface temperature in regions where temperature inversions are frequent and persistent.

The primary objective of the Western Atlantic Ocean Experiment was to determine the magnitude and fate of the sulfur and nitrogen oxides that move eastward from North America. Of the sulfur emitted into the atmosphere of eastern North America, about 34 percent is advected eastward; of this amount, about 50 percent moves east of 65 degrees longitude. At all altitudinal levels considered transport is important.

The eruption of El Chichon volcano in Mexico emitted large quantities of sulfur into the stratosphere and focused attention on the chemical reactions that would follow. These reactions are relevant to the sulfur transformations in acid deposition. Based on modeling efforts it was concluded that the oxidation of sulfur dioxide and hydrogen sulfide in the presence of nitrogen oxides does not consume ambient hydroxyl radicals, which is consistent with recent laboratory studies.

The enormous volume of data associated with the acid rain research effort will be made available to scientists through a system developed during FY 1983. The files of data together with the necessary information about the source, instrumentation, methods of reduction, and quality assurance are being assembled in a common format, so that individual investigators may use them interactively and thus improve productivity in researching model development and evaluation.

FUTURE ACTIVITIES

During FY 1984, the basic modeling system framework for the RADM will be established and case study periods selected to represent key climatological types important to understanding acid deposition. This initial phase of model development provides an operating system in which modules and components being developed at other institutions may be incorporated. The NCAR model development project needs preliminary outputs from the Natural Sources and Man-made Sources Task Groups to form a suitable emissions inventory by the end of FY 1984. The model will evolve during the next 2 years, with preliminary assessment results expected by late 1985. The final version of the RADM will be completed in early 1987, with documentation and source-receptor assessments completed later that year for the Assessments Task Group.

An exploratory field study of urban contribution to acid rain precursors will be conducted in early 1984. This will be used to examine the sampling and analysis procedures as well as the overall experimental design for the field study the following spring.

A study of recent acid precipitation trends in the eastern United States began during FY 1983. Spatial and temporal trends in sulfur and nitrogen emission rates will be compared to trends in acid deposition to establish whether a correlation exists.

A feasibility study for a regional field investigation is underway to relate acid deposition to precursor emissions. If funded, it would be managed by several governmental and other groups amd would establish direct empirical relationships between sources and receptor locations.

An international sulfur deposition model evaluation study will continue. An international group of modelers (five U.S., two Canadian, and three European) has been assembled by the EPA and Environment Canada to evaluate sulfur deposition models. This activity has been coordinated with the Man-made Sources Task Group whose emissions data will be used in the model applications. A series of reports is planned.

INTERRELATIONSHIPS

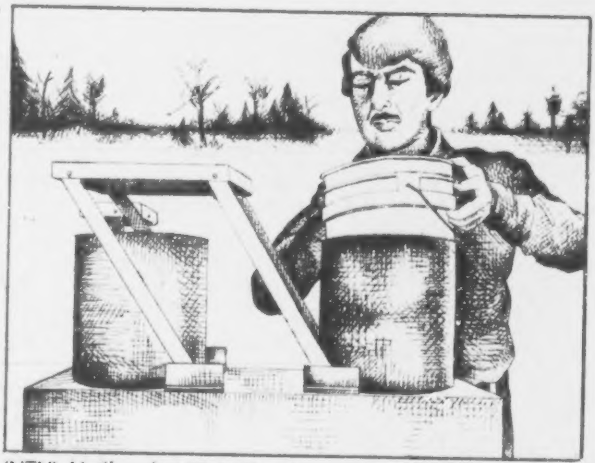
The development and improvement of credible predictive models is directly linked to the Natural Sources, Man-made Sources, Deposition Monitoring, and the Assessments Task Groups' activities. Considerable interaction with these task groups will continue since data must be collected to verify the models. Research-quality emissions inventories must be developed if the modeling effort is to succeed. Ultimately, these models will allow more reliable assessment of source-receptor relationships and provide the Assessments Task Group with a basis for evaluating various emission control strategies.

The private sector has done valuable research in atmospheric chemistry, atmospheric transport, and mathematical modeling of acid deposition. The Electric Power Research Institute (EPRI) is the major sponsoring agency with the automobile manufacturers next. Most of this funding has gone into basic field research, while a smaller fraction has been used in applying mathematical models to specific pollution situations. EPRI is also planning a study to determine the feasibility of using tracers for massive field studies.

The Government of Canada is sponsoring research in atmospheric processes. Cooperative research will be pursued with the Canadians in several areas, for example, Canadian participation in the CAPTEX experiment and comparison of Eulerian model developments.

D. *Deposition Monitoring*

BACKGROUND



Monitoring networks in the United States and Canada have developed a fairly complete initial picture of wet deposition chemistry in eastern North America, although sizeable areas of the western United States are not yet adequately covered. Before the late 1970's, however, little or no historical data were collected on acid deposition. Much of the data collected since 1978 was under the sponsorship of the State Agricultural Experiment Stations as part of the National Atmospheric Deposition Program (NADP).

Since 1982 one of the priorities of the National Program has been the development of a nationwide long-term National Trends Network (NTN). Until the NTN is fully operational a joint NADP/NTN pool of data will be used for national reporting purposes. Operational coordination for both NADP and NTN is provided by the NADP program coordination office.

There are now more than 130 wet deposition monitoring stations in the combined NADP/NTN pool of trend stations. About three-fourths of these stations receive all or most of their support directly from the National Program. Most of the NADP/NTN stations in the pool are in rural locations. These sites monitor primarily the collective effects of upwind emission sources, usually at long range (50 to 600 kilometers) from the collector sites. Samples are collected weekly for analysis of sulfate, nitrate, calcium, pH, and other constituents. About 60 wet deposition sites operated by Canada under the Canadian Air and Precipitation Monitoring Network (CAPMON, formerly CANSAP) contribute data to the pool of monitoring sources of deposition monitoring near concentrated sources of emissions are done by State, local, and utility interests and for special Federal projects, most of which are funded outside of the National Program.

Network data suggest no striking changes in the pH of precipitation during the past several years (see Fig. D—1). While trends of sulfate deposition are still not definitive, the regions of highest deposition for the past several years coincide with the regions where emissions are highest, namely the Midwest and Northeast. Increases in nitrate deposition roughly parallel the increase of man-made emissions of nitrogen oxides.

Historically indirect evidence of acid deposition over the Northeast from remote surface water stations indicates stable or slightly decreased sulfate, with a corresponding increase in alkalinity, during the last 10 to 15 years. A gradual increase in sulfate at some surface water stations of the Southeast and West has also been observed in recent years along with a slight decline in alkalinity. These changes generally coincide with lower overall emissions of sulfur dioxide during the 1970's and increased overall emissions in the Southwest and West.

Precipitation data have shown generally higher concentrations of pollutants when rainfall is low. Fogs and mists have generally lower pH's than rain.

Annual average (precipitation weighted) pH values of 5.0 were reported in some remote areas of the world in 1982. These measurements demonstrate that a pH of 5.6, often considered normal for rainfall in the absence of pollution, cannot be considered a benchmark for comparison. In some cases, organic acids are believed responsible for depressing the normal pH to a value closer to 5.0 than the expected 5.6. These organic acids are presumed to originate primarily from natural sources. Over land, alkaline dusts and other substances routinely cause the pH of wet deposition to be higher than the expected 5.6.

In contrast to the sizeable wet deposition network, monitoring of dry deposition has barely begun. Both technical and financial reasons have limited the number of dry deposition sites to a handful of prototype stations. There are no widely accepted methods for monitoring dry deposition on a routine basis. Near emission sources, dry deposition is believed to be an important contributor, possibly a predominant contributor, of acid-forming substances, due in part to rapid settling of heavier particles. Nearly all of the research on dry deposition in North America is being done by agencies in the Deposition Monitoring Task Group.

Many of the uncertainties surrounding the deposition of acidic substances in the environment can be traced directly to lack of data, especially on the relative contribution of dry deposition and acidic substances in fogs, mists, and frosts. Until these parameters are better documented, it will remain difficult for effects researchers to link acid deposition with observed damages.

RESEARCH GOALS AND ACTIVITIES

Planning and coordinating atmospheric deposition monitoring under the National Program is the responsibility of the Deposition Monitoring Task Group. The goals of the National Program's deposition monitoring activities are these:

1. Determine the spatial and temporal variations in the composition of atmospheric deposition within the United States through the NTN.
2. Develop methods for the reliable measurement of dry deposition.
3. Continue and increase research on methods for deposition monitoring.
4. Support a Global Trends Network (GTN) through operating monitoring sites at remote locations throughout the world.

PROGRAM ACCOMPLISHMENTS—FY 1983

National Trends Network. Seventeen new stations were added to the NTN during FY 1983 making a total of 98 stations (of 150 planned) in operation at the end of the fiscal year (see Fig. D-2). A site review team visited all 150 sites, and is preparing a report describing its findings and recommendations. It is anticipated that about 140 stations will be operating by the end of FY 1984.

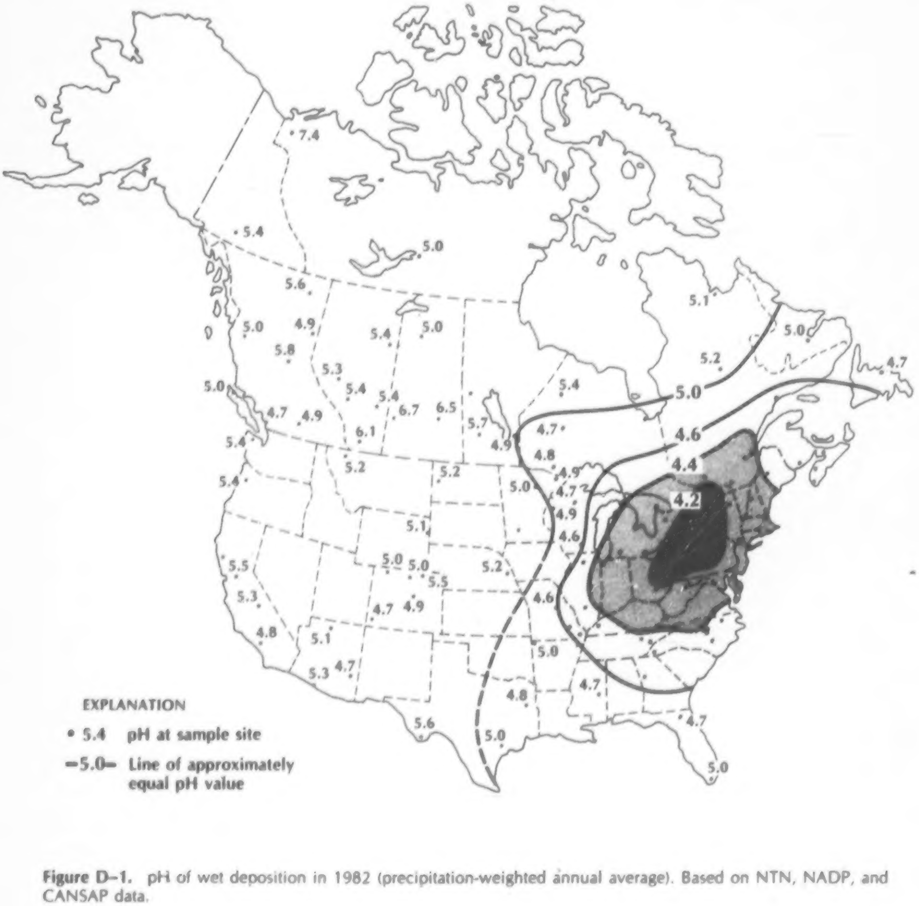


Figure D–1. pH of wet deposition in 1982 (precipitation-weighted annual average). Based on NTN, NADP, and CANSAP data.

Global Trends Network. Precipitation is collected at 10 or more sites annually around the globe on an event basis to determine its chemical composition and the processes that control it. Measurements in 1982 from seven remote sites have shown that the volume-weighted mean sulfate concentrations in precipitation are less than 15 percent and nitrate concentrations are about 5 percent of typical northeastern U.S. values. Measurements at GTN sites also indicate that the pH is influenced by organic acids such as formic and acetic acid. It is believed that observed pH increases in stored samples could be caused by the consumption of organic acids through biological activity (see Fig. D-3).

The Multi-State Atmospheric Power Production Pollution Study-National Research Network (MAP3S). The main objective of the MAP3S network is to provide long-term precipitation data on an event basis at nine locations in the Northeast. This is of great importance to ecologists and to atmospheric scientists developing and using atmospheric transport models. In addition, MAP3S provides a means of conducting field research not possible by the much larger NTN. For example, the Atmospheric Sciences Research Center of the State University of New York at Albany maintains a site in conjunction with its laboratories at the summit of Whiteface Mountain, N.Y. Whiteface Mountain, an isolated peak in the Adirondack region, collects atmospheric data remote from major emission sources. About 25 percent of the time, its summit is in clouds, providing ideal conditions for cloud chemistry monitoring experiments.

The New York Metropolitan Research Network. Event samples of precipitation were collected at four sites in the New York City area. These samples have been measured for pH and specific conductance, and analyzed for the major inorganic constituents known to affect acidity—namely, sodium, potassium, calcium, magnesium, ammonium, sulfate, nitrate, chloride, and phosphate. Variations in chemical composition from site to site have been observed for individual storms and for the annual mean values during 1982. Concentrations of sulfuric acid in precipitation were about 50 percent higher at the Lower Manhattan site in New York than at the two New Jersey sites during 1982; the Queens College site (New York) was intermediate.

Quality Assurance. The results of a laboratory and field measurements audit program indicate that NTN/NADP data are of consistently high quality. In January 1983 an interlaboratory comparability program was initiated with the Illinois State Water Survey (NADP/NTN laboratory), Environment Canada at Burlington, Ontario (CAPMON/laboratory) and the U.S. Geological Survey (USGS) laboratories at Denver and Atlanta. The National Coal Association's (NCA) monitoring laboratory (BCR, Inc.), was included in 1983. This program documents the analytical variability for most of the acid deposition data collected in North America.

A study of "within-site" variability and effects of sampling frequency conducted in cooperation with North Carolina State University has been completed and has contributed to a better understanding of sampling error. A separate study involving the joint location and operation of U.S. and Canadian samplers continued through the year. This cooperative study will document the variability resulting from samplers,

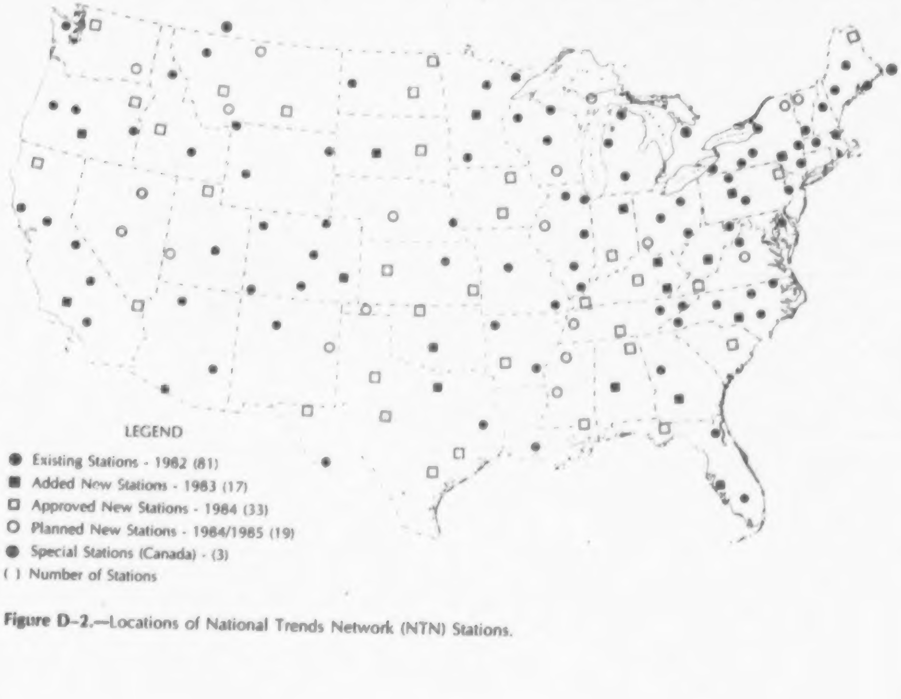

LEGEND
● Existing Stations - 1982 (81)
■ Added New Stations - 1983 (17)
□ Approved New Stations - 1984 (33)
○ Planned New Stations - 1984/1985 (19)
● Special Stations (Canada) - (3)
( ) Number of Stations

Figure D-2.—Locations of National Trends Network (NTN) Stations.

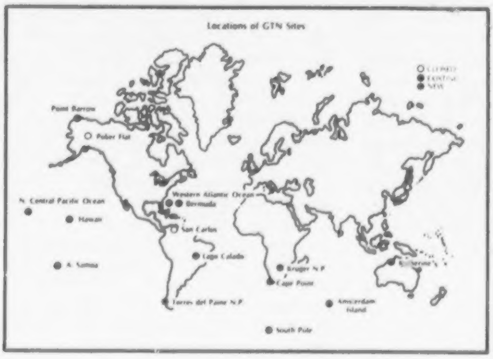
sampling frequency, equipment changes, and analytical differences between NADP, NTN, and CAPMON.

The Environmental Protection Agency (EPA) distributed a quality assurance manual covering both laboratory and field measurements of acid deposition. The first part of the manual identifies procedures to document the quality of the data collected. The second part provides general guidance on the operation and maintenance of wet precipitation samplers and the associated equipment. Work has begun to further refine those portions of the manual concerned with outlier rejection, sample stability, sample scheduling, and degree of collection required. The results of this work will be included in an updated version of the manual to be prepared in 1984.

Two stable, low ionic strength solutions for checking the calibration of pH electrodes were developed. The samples, which should be available for distribution in early 1984, are now being subjected to a round-robin test to determine the level of performance that should be expected for laboratories measuring precipitation. These solutions were developed because research has shown that the high ionic strength, pH electrode calibration solutions normally used are not satisfactory for calibrating electrodes that will be used to measure the pH of precipitation samples.

Atmospheric Research Sites. Three research sites for conducting special measurements and testing newly-developed equipment have been established. The sites are located at Pennsylvania State University, the Walker Branch Watershed in Oak Ridge, Tenn., and Niwot Ridge at high altitude in the Rocky Mountains in Colorado. Specific projects conducted at these sites include the development of sequential precipitation samplers, a study of how fog removes material from the air, and studies of the origin of acidity in remote areas, among others.

Dry Deposition Monitoring. The program envisioned under the National Program is designed to couple data on the concentration of gases, aerosols, and particulate matter in air with deposition velocity information to provide dry deposition loadings. The program features three major components: (1) a network of routine monitoring stations measuring air quality on a



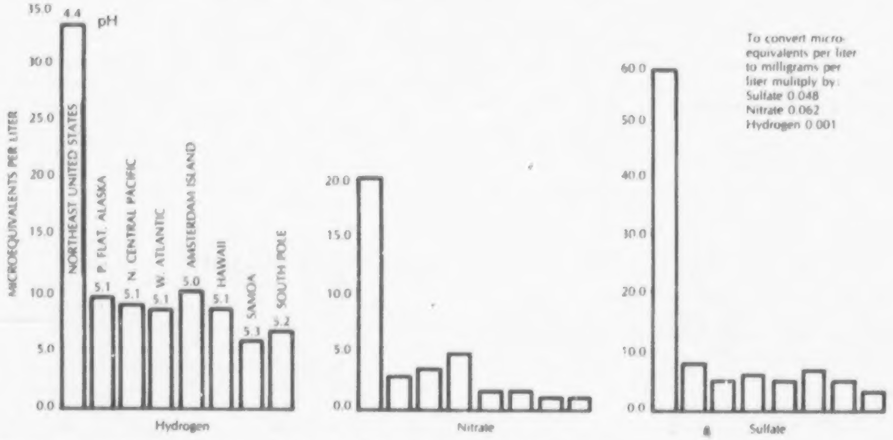


Figure D–3. Background data collected during 1982 at Global Trends Network sites as compared to the northeast United States.

weekly basis coupled with measurements of meteorological properties for determining appropriate deposition velocities; (2) a smaller network of core research sites at which the routine methods are augmented by periodic, intensive case studies using all available methods for measuring deposition fluxes directly; and (3) a data analysis and reduction facility for combining the concentration data with supporting meteorological data in order to calculate the deposition fluxes.

The Walker Branch watershed field site in Oak Ridge is one of three core research sites of the dry deposition monitoring program. Walker Branch has been instrumented to measure a wide variety of air chemistry variables and meteorological properties needed to deduce appropriate deposition velocities on a routine basis. Ozone, sulfur dioxide, and nitrogen oxide(s) are now monitored routinely, along with key atmospheric variables such as wind speed and atmosphere stability. A number of meteorological variables are reported for levels above and within the forest canopy surrounding the dry deposition monitoring site. The same field site is operated by Oak Ridge National Laboratory (ORNL) as a wet deposition monitoring site both of the NTN and the MAP3S precipitation chemistry networks.

Prototype air concentration monitoring devices coupled with meteorological measurement systems are presently being tested prior to installation at a few selected field sites in a collaborative program between National Oceanic and Atmospheric Administration (NOAA), EPA, Department of Energy (DOE), and USGS. The purpose of this pilot program is to test sampling and measurement equipment and develop methods for computing the deposition velocities required to calculate dry deposition fluxes from air concentration data.

Studies of the "eddy accumulation" technique for measuring dry deposition fluxes continue. A computer simulation of the method has been completed. A somewhat simpler method, tentatively referred to as "concentration accumulation," is presently being assessed. This new method uses a standard mass flow controller to sample air at a rate proportional to the time-varying deposition velocity appropriate for some selected trace gas or aerosol species.

Data Base Management. The Acid Deposition System (ADS) for data storage and statistical reporting of atmospheric deposition data has been established by the EPA at the Pacific Northwest National Laboratory (PNL). ADS provides an integrated centralized data bank for data collected by all atmospheric deposition monitoring networks in North America. The centralized data base facilitates access to deposition data collected by different organizations; provides annual inventories of available data; and maintains the data for the assessment of long-term national trends. A complete description of ADS is available in a system design and coding manual from EPA.

FUTURE ACTIVITIES

In FY 1984 the Deposition Monitoring Task Group will concentrate on implementing new sites for the NTN, developing methods and implementing a pilot program for monitoring dry deposition, and developing statistical packages for producing annual data system and NTN reports. Quality assurance programs will be expanded to include dry deposition.

National Trends Network. Coordination and operation of the NTN will continue, including establishing about 50 new sites in cooperation with several Federal, State, and private sector agencies. The task group will publish a report describing the design of the NTN and the results of the field visitation and evaluation project. NTN sites to be fitted with dry deposition monitoring equipment will be selected in cooperation with the NADP. The precipitation chemistry data collected under the United States/World Meteorological Organization/National Atmospheric Deposition Program have been analyzed and will be published for the period 1972-82.

Pilot Program for Monitoring Dry Deposition. A pilot program for monitoring dry deposition will concentrate on the deposition of trace gases and submicron aerosols since these are generally accepted as the major factors contributing to the dry deposition of acidifying substances. Because difficulties exist both in measuring and interpreting air concentrations, the proposed research program does not call for rapid deployment of a large number of routine monitoring sites in the very near future. Instead, it focuses on the immediate need to develop the necessary sampling and interpretative techniques, to test alternative methodologies, and to evaluate the alternative methods of interpretation. The program will develop improved air concentration measurement devices, test them in a prototype monitoring network, and develop methods for deriving dry deposition fluxes from air concentration data. A network of routine monitoring stations for assessing dry deposition will be set up after the conclusion of these tests, using equipment and techniques identified in the operation of a trial network of prototype instrumentation at five to eight selected NTN stations.

Statistical Summary Procedures. ADS will be expanded to handle dry deposition data for statistical analysis and reporting of dry as well as wet and total deposition data. PNL will investigate and estimate the probable errors involved in the various techniques for measuring deposition velocity of acidifying gases and aerosols in the atmosphere. As part of making the data base accessible to off-site users, an interactive summary and retrieval system will be added.

INTERRELATIONSHIPS

Interaction with other task groups is promoted by several organizational linkages, because members of the Deposition Monitoring Task Group are also members of the Aquatic Effects, Terrestrial Effects, and Materials Effects Task Groups. Different task group chairmen or sub-task groups meet as needed to discuss areas of mutual interest, for example, joint research at NTN sites or dry deposition budgets.

There are many interdependencies between the Deposition Monitoring Task Group and the Task Force.

For example, functional dependence of other task groups on the data from the NTN assures continued interaction in this area. Research and methods development for wet and dry deposition feed information to many task groups. Data analysis by researchers of the Task Force and others requires basic information from the GTN.

Monitoring of atmospheric deposition in the United States is being conducted outside the National Program by environmental research arms of the electric power industries and a number of State governments. Outside the United States, Canada has an extensive deposition monitoring program and Mexico has requested technical assistance from the United States in designing a nationwide program to be implemented in the near future. Close contact between the Deposition Monitoring Task Group and the Federal and Provincial governments of Canada is maintained through NADP and the International Activities Task Group. Three paired monitoring stations are operated near the border between the United States and Canada; at each, operators sample atmospheric deposition using both U.S. and Canadian methodologies. These direct comparisons of the two methodologies have been used to develop a basis for comparable, shared information between the countries.

Future plans include making MAP3S compatible with CAPMON by adopting identical protocols which include sampling gases and aerosols, as well as testing upgraded precipitation collectors controlled by a computer.

EPRI, the research arm of the electric utility industry, operates a 20-station network that is part of the Utilities Acid Precipitation Study Program (UAPSP) Close contact is maintained between this task group and EPRI, including discussion of cooperative efforts in quality assurance Co-location of one or more new NTN and UAPSP sites is being considered to provide a direct comparison between the two networks.

The NCA is conducting atmospheric deposition monitoring near coal-mining areas at 47 locations in 18 States from the Rocky Mountains to the Atlantic Ocean. At the urging of the task group, NCA has agreed to make its monitoring data generally available and to participate in a cooperative analytical quality assurance program.

Several States, including California, Florida, Iowa, Massachusetts, Minnesota, Pennsylvania, Virginia, and Wisconsin have their own statewide deposition monitoring programs, and more States are planning such programs. A compilation of State-sponsored research on acid deposition will eventually be included in the National Program's computer inventory. The Deposition Monitoring Task Group plans to work with these State agencies with respect to methods standardization and analytical quality assurance.

E. *Aquatic Effects*

BACKGROUND

Acid deposition has been identified in some scientific reports as contributing to both long- and short-term depressions in pH and reducing alkalinity in some lakes and streams in the United States. Only a very small percentage of U.S. lakes and streams are thought to have lost all alkalinity because of acid deposition. Elevated concentrations of toxics, such as aluminum, and biological effects, including declining fish populations, have accompanied some pH depressions. Clear relationships have not been established between acid deposition and observed aquatic effects.

Current knowledge does not make it possible to quantify the dose-response relationships for aquatic ecosystems. Based on several empirical studies, long-term water quality data, and numerous sediment cores, it can be inferred that acid deposition has caused or substantially contributed to some long- and short-term alkalinity reduction in certain low alkalinity surface waters of the United States. The purpose of the extensive research efforts in the Aquatic Effects Task Group is to quantify such dose-response relationships as soon as possible.

The sensitivity of surface waters to acidification is usually based on alkalinity. Alkalinity is a measure of the degree to which water resists changes in pH upon addition of strong acid. A national inventory of pertinent data has gathered a large number of recent and historical records of surface water chemistry. Data from the inventory have been used to construct maps of surface water alkalinity to define those regions where lakes and streams are likely to be most sensitive. These historical records are being analyzed to determine whether alkalinity, pH, or sulfate have changed over time. Such analyses may indicate whether a general loss of alkalinity has taken place (see Fig. E-1).

Some of the trends show increases in sulfate and corresponding decreases in pH and alkalinity for some lakes and streams. Others show the opposite or no relationship. Cause and effect relationships, however, are difficult to demonstrate when analyzing the entire body of data, and natural chemical and biological variation further complicate the detection of trends even when they exist.

The Adirondack Mountains receive highly acid deposition and constitute one of the more sensitive lake districts in the United States. For example, 52 percent of 214 high elevation lakes sampled in 1975 have pH values less than 5.0. Farther north, a study of 95 small, low alkalinity lakes in New England for which historical data are available reported that 64 percent have undergone statistically significant pH decreases. Two other studies have indicated apparent pH decreases in some low alkalinity lakes surveyed in Maine. Preliminary studies have estimated that a small number of lakes in northern Wisconsin and Michigan with pH values less than 5.0 may at least partially reflect the effects of acid deposition. On the other hand, other low alkalinity lakes in Wisconsin have either not changed or increased slightly in alkalinity over the past 40 years.

A complex set of factors governs the response of surface waters to inputs of acidic substances. Bedrock and surficial materials may neutralize or retain acidic inputs. The pathways that precipitation and snowmelt follow before entering a stream channel or lake determine which of the available materials the water may contact and for how long. Both factors are important in controlling dissolution or exchange reactions that modify acid precipitation. Of particular importance is the mobilization of aluminum from soils. Certain inorganic forms of aluminum are toxic to fish and other plant and animal life.

Basic research on forested catchments is often jointly funded with the Terrestrial Effects Task Group. Research to study chemical reactions of acids that reach streams and lakes eventually should allow the formulation of improved empirical and process models that can be used to predict the ultimate effects of acidic inputs on the chemistry of surface waters.

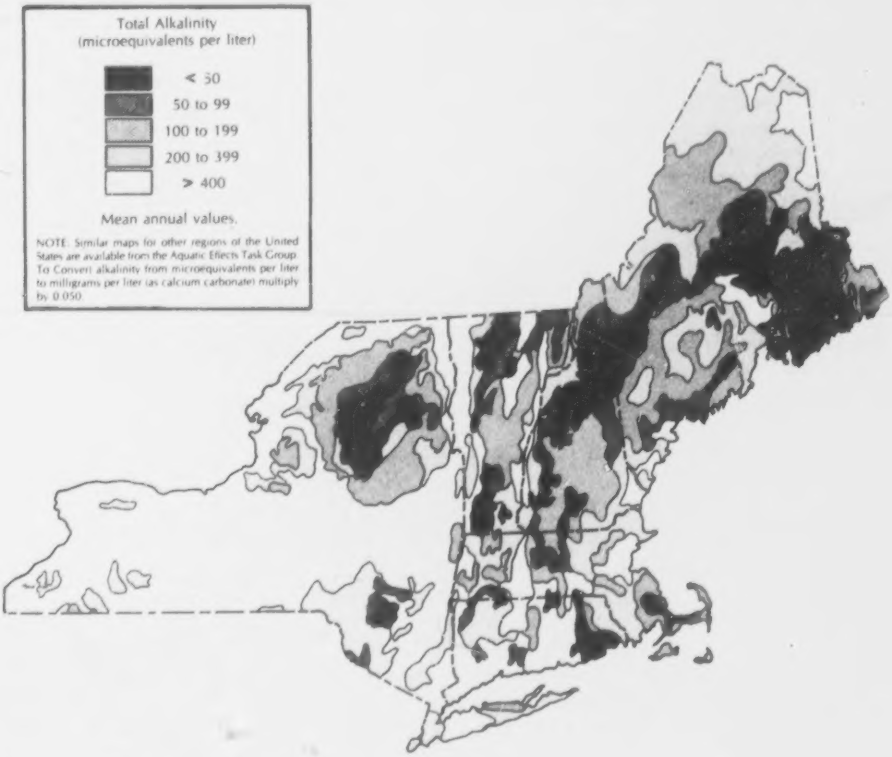
Comparison of 1930's data from the Adirondack Mountains with recent surveys shows that at least 180 former brook trout ponds are acidic and no longer support brook trout, although a direct association with acid deposition was not established (see Fig. E–2). Loss of fish populations related to acidification caused by acid deposition has not been documented anywhere else in the United States. In no areas is the relative contribution of natural and man-made sources to acidification of lakes and rivers well known.

Many species of amphibians breed in temporary pools formed by the mixture of spring rains and snowmelt. Many such pools are subject to low pH conditions. Embryonic deformities and mortalities in the yellow-spotted salamander have been observed where the acidity of meltwater pools was lower than that of nearby permanent ponds. These data are very limited in scope, and therefore, the geographic extent of any effects is not known.

With few exceptions, the mechanisms of acidification effects (whatever the cause) on fish, amphibians, and other aquatic organisms are poorly understood. Biological changes can occur as pH declines below 6.0 and can become increasingly severe as pH declines further. Aluminum and other potentially toxic elements can be released into acidic waters and contribute to biological changes. These effects are currently known only qualitatively, except for the dose-response relationship between aluminum and selected fish species.

Liming is one option for temporarily protecting and possibly restoring acidified aquatic systems. In this context, liming is a generic term indicating the addition of any alkaline substance to surface waters, sediments, or soils to neutralize them or increase alkalinity. Preliminary study and application of liming (primarily in Scandinavia) have indicated that some short-term protection or renovation of affected surface waters is possible. However, these studies are incomplete and important questions remain regarding the long-term biological consequences of liming, its costs, method of application, materials used and their chemical reactions, impact of episodic events, and fisheries management.

Field tests conducted in North America and Sweden have shown that powdered limestone appears to be the most economical and effective reagent. However, there are possible disadvantages, such as the precipitation of aluminum in lakes and possible resolubilization during acidic episodes (such as spring snowmelt). Liming of streams has also been attempted, but with generally less satisfactory results. Permanent limestone structures in streams become ineffective because of biological fouling, and lime slurries are quickly dissipated, requiring continuous and expensive maintenance. Diversion wells and rotating drums appear practical at some sites.



NOTE: Similar maps for other regions of the United States are available from the Aquatic Effects Task Group. To Convert alkalinity from microequivalents per liter to milligrams per liter (as calcium carbonate) multiply by 0.050.

Figure E–1. Alkalinity of surface waters in the northeast United States.

RESEARCH GOALS AND ACTIVITIES

The major goals of the Aquatic Effects Task Group's research are to quantify the effects of acid deposition on lakes, streams, ground waters, and wetlands of the United States; describe how these effects can be corrected; and determine the ecological consequences of acidification and remedial methods. Research will also provide information needed to predict the likely sites of future water quality changes under steady or changed acid deposition rates. The extent and magnitude of changes in the ecosystem's plant and animal life associated with changes in the chemistry of lakes, streams, and wetlands will also be investigated.

Research on aquatic effects focuses on five major objectives:

1. Quantify the extent of sensitive and acidic lakes, streams, ground waters, and wetlands of the United States.

2. Identify and quantify the factors that control the sensitivity of surface and ground waters to acid deposition and determine how these factors can be used to predict aquatic acidification under different loading rates.

3. Determine the relationships between surface water acidification and biological processes, biological populations, and aquatic communities and how these relationships can be used to predict ecological effects.

4. Determine the potential effects of freshwater acidification on human health.

5. Develop mitigative techniques for restoring or protecting acidic lakes, streams, and ground waters of the United States.

Throughout FY 1983 the Aquatic Effects Task Group reviewed all current and planned aquatic effects research projects to evaluate their relative priorities. The task group has assured that all researchers will use compatible laboratory and field methods and will deviate from standard methods only for valid scientific reasons.

PROGRAM ACCOMPLISHMENTS—FY 1983

Assessment of the extent of acidification (from deposition) of lakes, streams, and ground waters of the United States. This multiagency effort brings existing water quality data together on a national scale to assess the extent and degree of sensitivity to acid deposition in U.S. lakes and streams.

The project will assist the analysis of trends in the acidification of surface waters and provide a verified, quality assured data base for models to predict surface water acidification based on given deposition rates. This will help correlate geographic patterns of surface water sensitivity and acidification with climatic, geologic, physiographic, soil quality, and land use factors.

In FY 1982 and 1983 the Aquatic Effects Task Group inventoried existing national water quality data that applied to this problem. Additional information was compiled from supplementary synoptic field surveys in New England, the southern Appalachians, the Upper Midwest and the West. These data are currently being used in the analysis of historical trends and regional maps indicating general patterns of surface water alkalinity. A network of lake and stream long-term monitoring projects was established to determine future changes in the quality of surface waters related to deposition and its effects.

Long-term program to monitor the chemistry and plant and animal life of surface waters in sensitive sections of the United States. By quantifying the current effects on aquatic systems exposed to a range of acid

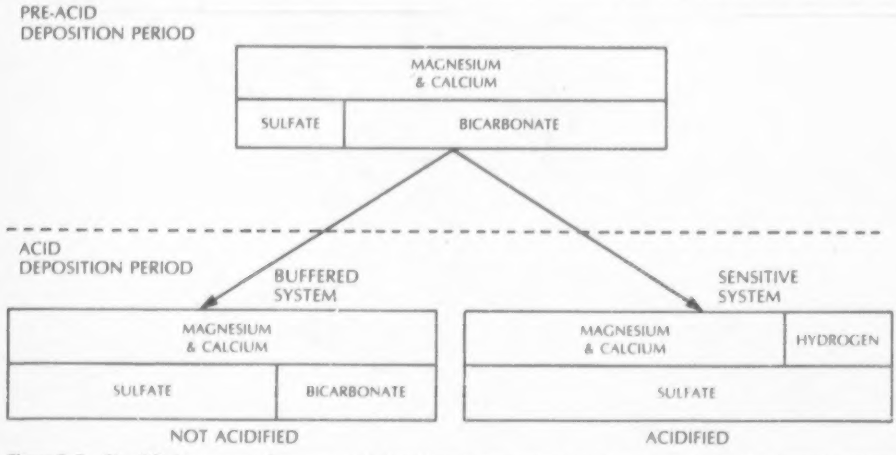


Figure E–2. Simplified response to long-term acid deposition: Two extremes for the response of simplified aquatic systems to a fivefold increase in sulfate. The length of the boxes portrays relative amounts.

loading rates, this program is providing information needed to make recommendations for acceptable atmospheric loading rates of acidic materials. The task group developed a standardized sampling and analysis protocol for measuring the chemistry of surface waters, including the long-term monitoring program. Sites for long-term monitoring of lakes and streams have been identified. Annual reports from each site will be combined into an overall annual summary report.

Compilation of data on the current and historic status of fish populations in the northeastern United States. Beginning in FY 1983, data on the presence of fish and their population status are being compiled from State and Federal agencies and private individuals and computerized to support trend analyses. This information will be analyzed and made available for the FY 1985 Assessment being developed by the Assessments Task Group.

Preliminary protocol for sampling biological communities. A workshop in July 1983 identified biological variables of interest and recommended sampling techniques, frequency, and quality assurance procedures for studies and monitoring programs. The final report will be completed in FY 1984.

Accelerated studies to identify, quantify, and predict the factors controlling the susceptibility of natural waters to acidification. These research projects will lead to a predictive modeling capability. The Aquatic Effects Task Group has completed a thorough review of the existing models for predicting acidification. The task group will use several of these (or other approaches to be developed) to predict future acidification of surface waters based on different acid loading rates for the FY 1985 assessment.

Integrated lake acidification project in northern Wisconsin. One of the best ways to identify and quantify impacts of acidification on aquatic ecosystems is through whole-system experimental manipulations. Half of Little Rock Lake in northern Wisconsin will be gradually acidified in a field experiment. The unacidified half of the lake will serve as a control for the experimental acidification. Collection of background preacidification data began in FY 1983. A number of State and Federal agencies are cooperating, as well as several universities.

Laboratory and field bioassays on the toxicity of pH and aluminum to fish. Experiments are continuing to improve our understanding of toxic thresholds, the relative sensitivity of fish species to acidification, critical phases in fish life cycles, and the importance of episodic pH depressions on fish survival. Experiments are concentrated on economically and recreationally important species and those particularly sensitive to low pH. Some bioassays have also been completed on the toxicity of heavy metals at decreased pH.

Survey of eastern surface and ground water supplies. This completed survey dealt with the quality of drinking waters and source waters in the New England States, the New York Adirondack region, the New Jersey Pine Barrens, and the Appalachian Mountain region of Pennsylvania, West Virginia, and North Carolina. Results, although still under analysis, indicate that many of the waters surveyed are corrosive, as expected, but that lead, cadmium, and mercury levels in drinking water rarely exceeded the levels recommended by the Environmental Protection Agency (EPA). Adverse effects of acid deposition on human health through ingestion of surface water were not demonstrated in this study. A review of the ground water data revealed that water from silica sands had the lowest pH.

Evaluation of mitigation strategies for restoring or protecting lakes, streams, and watersheds. A report was issued summarizing available information on liming, including State, Federal, and private sector contacts for liming projects. It also presented a technical evaluation of liming projects in the northeastern and midwestern States. Research projects in Scandinavia and Canada were included in this report.

Field tests to lime lakes sensitive to acid deposition. This project concerns the development and testing of management procedures and techniques for temporarily protecting lakes and streams from the harmful effects of acid deposition, acidification, and associated toxic metals. Tests involving both laboratory and field investigations were run on surface waters where fish populations have either been reduced or are under stress because of acidification. A related laboratory and field project was begun on placing limestone gravel in spring upwellings as a possible mitigation measure to enhance spawning in acidic brook trout lakes.

Evaluation of limestone contactors for drinking water treatment under field conditions. A field evaluation showed that a limestone contactor can increase the pH of water from an acidic lake and ground water and therefore decrease the tendency for that water to dissolve copper and lead from plumbing. Related laboratory work evaluated the chemical reactions of limestone dissolution. The mathematical model being developed from laboratory column studies should also be applicable to projects placing limestone gravel in spring upwellings of lakes.

FUTURE ACTIVITIES

Major FY 1984 and 1985 priorities of task group research are to (1) continue to make substantial progress in assessing the extent of surface water sensitivity and strengthening the comprehensive, long-term surface water monitoring program; (2) develop a better understanding of the geochemical linkage between terrestrial and aquatic systems; (3) survey biological communities in regions at risk from acid deposition and develop preliminary estimates of current and future damage to aquatic resources, particularly fish populations; (4) complete drinking water surveys of the eastern United States; and (5) expand the range of field tests to evaluate liming as an option.

Specific highlights of expected FY 1984 accomplishments are as follows:

Regional maps of sensitive waters of the United States. Current maps are not of sufficient detail or accuracy to allow for in-depth assessments. Detailed regional maps developed in FY 1984 will provide much greater detail and be based on more data. The proposed national synoptic survey based on these maps will substantially increase our data base on low alkalinity lakes and streams.

Preliminary report on quantification of the extent and scope of surface waters at risk in the United States. Although national and regional maps are critical to the assessment of surface waters at risk, a quantitative and statistical analysis of all relevant data from the national synoptic survey (alkalinity, pH, sulfate, and others) will provide an inventory of acidified waters and simultaneous analysis of watershed data, water chemistry, and atmospheric deposition data.

Report on historical trends in surface water acidification from lake sediment coring studies. An alternative approach to detecting historical trends in lake water chemistry is stratigraphic analysis of bottom sediment cores. Core samples yield independent records of past chemistry and biology in a lake. These findings can then be compared with trends deduced from historical analyses of water chemistry or historical emission inventories.

Interim reports on lake, stream, and reservoir monitoring. Low alkalinity, sensitive surface waters have been surveyed and are being monitored in the Rocky Mountains, Upper Midwest, New England, Adirondacks, Catskills, and middle and southern Appalachians. Results will quantify the distribution of these sensitive waters and their response to acidifying factors. This work will also be used to design a national synoptic survey.

Synoptic survey of chemical characteristics and biological communities in acidic and sensitive waters. A synoptic survey is being designed to cover the sensitive areas of the United States and measure water chemistry and key biotic parameters. This survey will quantify many of the Nation's low-alkalinity and acidic waters.

Preliminary report on analysis of causative factors for increases and decreases in alkalinity and pH. Data from the national synoptic survey will help analyze geographical trends in water chemistry and determine whether they are related to atmospheric deposition.

Preliminary report on historical trends in fish populations in lakes in the northeastern United States potentially affected by acid deposition. Current and historical data on the status of fish populations are being compiled within Fish Information Network. Changes in fish populations through time will be assessed relative to other data bases on historic trends in surface water acidification.

Final report on biological sampling protocol. Recommended methods for assessing and monitoring impacts of acidification on aquatic communities will be outlined. This protocol will be used in long-term monitoring and synoptic surveys as much as possible.

A preliminary empirical model relating the presence or absence of fish species in lakes to acidification. Based on results from synoptic surveys of fish populations in the northeastern United States, Wisconsin, and the southern Appalachians and correlations of fish populations with water quality and watershed characteristics, a simple empirical model will be developed for a preliminary estimate of regional damage from acidification. This estimate will be provided to the Assessments Task Group for the 1985 Assessment.

INTERRELATIONSHIPS

The National Program's research is periodically reviewed by a panel of outside experts to ensure that each project contributes to the identified objectives, milestones, and deliverables. A government-wide technical peer review of aquatic effects research in February 1983 allowed the National Program's research to be reviewed in a comprehensive manner rather than as a series of discrete agency projects; assessed the quality of the science; provided a forum for interaction by field-level scientists; and evaluated the progress of the various research approaches. A summary report of the reviewers' comments was issued in April 1983.

Several aquatic effects projects are conducted jointly with the Terrestrial Effects Task Group. In fact, several members of this task group are also members of the Terrestrial Effects Task Group. A representative from the Assessments Task Group is also a member of the Aquatic Effects Task Group to ensure coordinated research and timely input for the assessments.

The Aquatic Effects Task Group will provide four estimates of present and future aquatic damage by late 1984 to the Assessments Task Group to be used in the overall assessment of current damages in FY 1985.

The Aquatic Effects Task Group will continue to cooperate with the Electric Power Research Institute's (EPRI) Ecological Studies program which includes research on aquatic systems and natural managed terrestrial ecosystems, such as crops, forests, and grasslands. Part of this program includes the Integrated Lake Watershed Acidification Study (ILWAS) which is attempting to determine the relative role of acid deposition in the acidification of surface and ground waters and to develop a predictive model of watershed acidification. Other major EPRI studies involve aluminum transport, biological effects, and liming effects. The Environmental Protection Agency (EPA), the Fish and Wildlife Service (FWS), and the U.S. Geological Survey (USGS) are closely involved with these studies.

A major new multi-agency project entitled Fisheries and Lake Acidification will examine the responses of three important fish species to acidic conditions. It will attempt to develop and evaluate a simplified fish response model. Several experienced research groups are cooperating on this project, including EPA.

A few research programs sponsored by State governments are currently underway, while other States are actively examining the possibility of establishing such programs. Wisconsin, California, New York, Vermont, and Minnesota, in particular, have active aquatic effects research programs.

Several projects supported by grants from the National Science Foundation (NSF) should contribute information useful to achieving the objectives identified by the Aquatic Effects Task Group. Weathering reactions and cation exchange in lake sediments are being studied experimentally at the Experimental Lakes Area (Kenora, Ontario) to understand their role in hydrogen ion uptake, alkalinity production, and lake buffering capacity. Other projects at Hubbard Brook Experimental Forest, N.H., are examining the fundamental processes of acidification in forested watersheds, especially the chemical processes controlling the mobilization and transport of aluminum. Much useful background information about biogeochemical cycling processes and patterns of nitrogen, sulfur, and carbon is available from several projects broadly distributed across the United States in representative ecosystems.

Many of the scientists and managers involved with the Aquatic Effects Task Group are also involved in the United States-Canada Memorandum of Intent on Transboundary Air Pollution. To facilitate close communication between aquatic researchers, Canadian and Scandinavian scientists are invited for the peer reviews and other major meetings of the task group.

F. *Terrestrial Effects*

BACKGROUND

Concern is mounting in the United States because of observed forest decline. Hypotheses to explain this decline are being tested. These hypotheses involve various pollutants acting alone or in combination, such as sulfur dioxide, nitrogen oxides, trace metals, ozone, and acid deposition. Disease and climate are known to affect the growth and vitality of forest stands. Combined pollutant effects are being studied intensively, although soil-mediated processes have not been ruled out as a possible cause. A complex cause is likely for the observed changes. The National Program places priority on the research of effects of acid deposition on terrestrial ecosystems.

Research on the terrestrial effects of acid deposition is complicated by many possible environmental interactions. Acid deposition is composed of various combinations of sulfur and nitrogen compounds, depending on season and location. Additionally, it falls in both dry and wet forms. These variables relate to both expected effects and the way they must be studied. Additional complexity comes with the possible interactions with other air pollutants and natural processes and stresses. Many of the unanswered questions could have significant impact on mitigation and emission control policies.

Our understanding of acid deposition and its possible effects on terrestrial ecosystems is increasing rapidly. Its composition, temporal variability, and extent are being identified. Research suggests that toxic aluminum movement through soil and into surface waters may be related to periods of high acid influx. Continuing research substantiates that some species of trees in the Northeast and Southeast have slowed markedly in growth over the past 20 years. This growth reduction has not been linked to acid deposition, but it may play a role (see Fig. F-1). Research on agricultural crops has shown most crops tested are not affected by acid rain in the pH range of 4-4.5 or the current average ambient level for highly affected areas.

RESEARCH GOALS AND ACTIVITIES

The terrestrial effects research of the National Program is organized within four major subject areas: forests and rangeland productivity, soil processes, watershed processes, and crops. The program is designed to address policy needs as well as the understanding of how acid deposition may affect terrestrial ecosystems. Research will concentrate on several questions in each category:

Forests and Rangelands

1. Does acid deposition have long-term effects on forest and rangeland productivity?

2. Under what conditions, if any, will acid deposition be detrimental to forest and rangeland ecosystems and what are the functions, processes, composition, and stability of these systems?

3. Can techniques be designed to counteract any adverse impacts of acid deposition on forests and rangelands?

To examine the effects, magnitude, and mechanisms of acid deposition on forest productivity, the Terrestrial Effects Task Group is investigating forest growth trends and studying the relationships of physiological processes. Possible interrelationships among acid deposition and other potential stress factors are being investigated. Other studies emphasize species composition and successional dynamics, metal toxicity, and direct acid impacts.

Soils and Watersheds

1. What are the impacts of acid deposition on soil chemistry and biological productivity?

2. Does acid deposition affect soil processes such as leaching, weathering, ion mobility, and organic matter decomposition?

3. How does acid deposition affect the linkages among soil, water, and plant components?

4. Are there effective techniques for mitigating adverse impacts of acid deposition on soils and watersheds?

Studies on soil chemistry with emphasis on cation and aluminum mobility and acid buffering capacity are being emphasized. The sulfur budget is being documented for soils in hardwood forests, and the fate of nitrogen compounds depositied on forests soils is being investigated. The ability of watersheds to absorb acid deposition components is also being determined.

Agricultural Crops

1. What are the threshold doses of acid deposition that affect crops either adversely or beneficially?

2. Can mathematical models be developed to estimate economic losses in major crop plants?

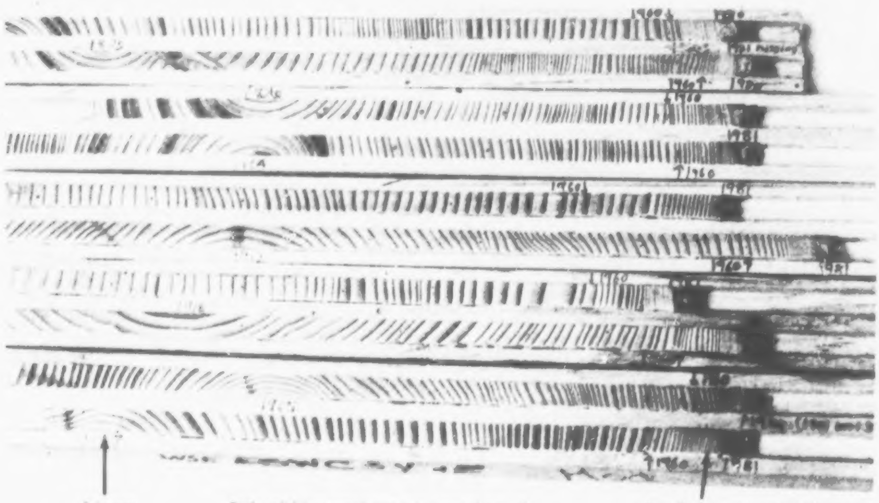
Agricultural research is focusing on selected economic crops such as corn and soybeans, and concentrating on those questions that can be effectively addressed within a 5-year time span. The emphasis is to generate realistic response functions that can be used in an assessment.

PROGRAM ACCOMPLISHMENTS — FY 1983

Forests and Rangelands. Research is proceeding to determine the effects of acid deposition on nutrient availability and long-term soil fertility. The interaction of forest insects and pathogens with acid deposition is being studied using both forest stands and precipitation exclosures. Studies have begun on the effects on forest productivity, reproduction, regeneration, and physiological processes, including the role of forest ecosystems in buffering acid deposition. The current and past growth rates of forest trees in areas subject to acid deposition are being assessed; also of concern is the effect on growth of acid deposition combined with other air pollutants.

During the past year scientists found that precipitation with a pH range of 4.6-3.6 did not adversely affect tree seedling growth. However, sustained exposure to acid fog altered leaf morphology of yellow poplar. Preliminary analysis of data from experiments on loblolly pine growing on two soil types shows no effect of pH 3.0 rain alone on seedling growth. However, on one soil type, the growth reduction from pH 3.0 rain and ozone together exceeded the reduction from ozone alone. On the other soil type, no interaction was detected. In the field, forest canopy types were found to vary in their ability to neutralize acids in precipitation. For example, tulip poplar was most effective and eastern hemlock the least effective in stands studied. Research on the effect of acid rain on tree pathogens indicates that some plant parasites are inhibited by acidity levels that occur in ambient rainfall.

Studies examining historical trace element accumulation within tree growth rings show that iron and titanium levels correspond with known emission sources and dynamics as far back as 100 years. Recent increases in these elements correlate well with increases in atmospheric deposition in the last 25 years



1st year

Each solid line represents one year of growth.

Rapidly narrowing space between lines indicates stress or stresses.

Figure F–1. Tree ring cores from red spruce at Mt. Washington, N.H., showing radical growth decline after 1960.

and in some cases raise concern about potential toxic reactions. Chemical analyses of wood may provide an historical record of deposition and uptake of trace elements. Comparisons of tree growth rate and chemical accumulation may be one method of documenting cause and effect relationships.

A major study of tree growth rates in the eastern United States continued with the cooperation of the EPA, USGS, and the Department of the Interior (DOI). Widespread and sustained growth reduction is being documented in several species which is not consistently related to climatic change or tree age. Studies of high elevation forests in the northeastern United States have documented significant growth decline and mortality of red spruce. The relationship of these changes to both atmospheric pollution and natural stress is being investigated.

Soils and Watersheds. One of the main objectives of research on soils and watersheds is to gain enough knowledge to describe and predict the impacts of acid deposition on stream and lake water quality. This research will also lead to an understanding of the long-term effects of acid deposition on fertility, toxicity, and productivity of soils as related to plant growth. The fate of minerals, ions, and acids deposited from the air is being determined. The composition and form of acid deposition are being measured. Scientists are studying the buffering capacities of soils and watersheds and relating them to forest type, parent material, and other variables. The key question of cation mobility within and out of forest soils is being studied. Results of this research are being produced in a form that can be used in predictive models or incorporated directly into the assessment computations.

Research on the sulfur budgets of select forests in the southeastern United States has progressed to the point of identifying the relative distribution of input types, pathways through the forest canopy, and total sulfur pools in these ecosystems. A large variation in the ability of forest soils to buffer acid precipitation was found in the northern lake States. For example, water outflow from organic soils under spruce yielded a pH of 3.5 to 4.6, aspen on glacial till a pH of 5.4 to 6.2, and red pine on granitic soil was identical to the incoming rain of 5.5 to 4.4 (Soil organic acids probably account for some of these differences.) This helps explain the different levels of acidity that lakes are exposed to, which depend largely upon characteristics of surrounding watersheds.

Intensive rainfall studies at Coweeta and Hubbard Brook experiment forests for 10 and 20 years, respectively, show no significant increase in acidity although it varies greatly by month, season, and year. Much of the incoming sulfate was converted to a seemingly immobile form of sulfur by soil microbes.

The relative contribution of acid deposition to cation leaching from soils in several forest stands has been estimated. Thus far, research shows total cation export from leaching exceeds that from whole tree harvesting based upon mass balance calculations derived from sulfate analysis. Chestnut oak stands near Oak Ridge are an exception where harvesting and leaching are comparable.

Experiments with a sandy soil (Typic Quartzipsamment) in Florida showed a significant increase in cation leaching in the uppermost layers from rain with a pH of 3.7. Nitrification rates in some Florida soils were reduced at pH treatments of 3.7 and 3.0, corroborating research in Sierra Nevada soils. Analysis of data and modeling of White Oak Run in the Shenandoah National Park suggests that alkalinity may have been halved in recent years. Studies in the Rocky Mountain National Park do not show any significant effects of acid deposition on moderately sensitive lakes (less than 200 microequivalents per liter of alkalinity).

New insight into the processes that determine the transfer between soil solution chemistry and surface water acidity has developed using process models. Model refinement is improving our ability to predict the impact of acid deposition on ion removal and leachate chemistry. A plausible mechanism has emerged for soil-mediated processes where surface water acidification may result from acid deposition.

Agricultural Crops. There is concern that acid deposition alone or in combination with other air pollutants is decreasing agricultural production. Although the effects of photooxidants have been studied for many years and serious damage documented, we have very little information relating specifically to acid deposition. Research has begun to determine the separate and combined effects of wet and dry deposition acid and oxidants on important agricultural crops typically grown in affected regions. Evidence shows little if any impact of acid deposition on most crops in pH ranges typical of current conditions.

Sophisticated systems for testing the effects of wet acid deposition on field crops have been completed and successfully used. During the 1983 growing season, simulated acid rain did not affect the yield of potatoes. Transitory foliar necrotic lesions were detected on soybean seedlings exposed to pH of 3.2 or less, but overall soybean leaf area damage was small, and apparently did not affect yield. Two varieties of corn were found to be insensitive to simulated acid rain as strong as pH 3.4 after one season of testing. Two varieties of soybeans were tested with simulated acid rain in Illinois and one (Williams) was found to be insensitive while another (Amsoy) showed an 8 percent decrease in yield between a pH of 4.2 to 5.6. These varieties represent 15 percent and 3 percent, respectively, of the soybean crop. This is similar to results previously found at Brookhaven National Laboratory and represent multiyear experiments. Single year experiments on several other soybean cultivars have not shown any damage. Studies of the effects of wet and dry acid deposition and photooxidant interactions on crops were started.

FUTURE ACTIVITIES

Among the planned deliverables for 1984 are:

1. A state-of-the-art description of dose-response relationships for corn and soybeans.

2. A report summarizing the quantitative significance of forest declines by species and region and evaluating the scientific basis for attributing these declines to acid deposition, gaseous pollutants, or natural causes.

3. A report on the effects of acid precipitation on plant diseases.

4. U.S. Department of Agriculture (USDA) special research grants on forest ecosystems.

5. A monograph on acid deposition-soil interactions.

6. Reports describing the effects of acid deposition on soil microbiological and chemical characteristics.

7. A report describing sulfate mobility in acid soils and an assessment of models for describing cation movement within acid soil.

8. Initial report on aluminum tolerance of red spruce and balsam fir as conditioned by acid deposition.

These relate to the areas studied by the task group in the following ways:

Forests and Rangelands. Research on the effects of acid deposition forest and rangelands will expand next year. Existing long-term studies on forests and rangelands will continue. New studies will include microscopic investigation of the effects of aluminum on tree rootlets, the effect of acid deposition on growth of pine in New Jersey, mineral leaching from leaves, and the effects of acid deposition on respiration and photosynthesis. Additional studies of ozone-acid deposition interactions and plant growth will begin.

Research on the impacts of forest management activities such as harvesting and road building on stream quality will be expanded. Research on the growth rates of forest stands will be accelerated and will include wood density, trace element content, and understory vegetation dynamics. Evaluation of the possible role of air pollution, climate, and other environmental factors will intensify. Analysis of data from the Forest Service's national network of Continuous Forest Inventory plots will begin to determine their usefulness in detecting growth rate changes.

Initial studies of forest tree growth in the Northeast and studies of trace element content of wood have laid the foundation for a greatly expanded program designed to identify the relationships among acid deposition and forest impacts. Additional sample sites will be established in the Northeast and Southeast and more intensive sampling of trace elements, wood density, and associated important tree species will be emphasized. Trace element analysis will be expanded with the hope that this technique can be used to assess air pollution exposure of forests over large areas. Success thus far with laboratory studies of soil solution chemistry and acid precipitation have set the stage for expanding sampling to include the Northeast and Southeast. Testing and modification of large exclosures for field control have produced an improved version of this critical apparatus.

Soils and Watersheds. Future activities will build upon current findings and emphasize priority research. The Integrated Lake-Watershed Acidification Study (ILWAS) model, developed by the Electric Power Research Institute (EPRI), will be validated in several geographic areas. Additional research on the dynamics of sulfur compounds in forest soils will begin. Research on the interrelation of pH, soil type, and forest tree species will be expanded and the direct impacts of acid rain on alkali-poor forest soil determined. Long-term stream chemistry trends, as well as storm, monthly, seasonal, and annual variation in the Southeast will be analyzed and published.

Soil nutrient losses caused by acid deposition and harvest will be compared and related to soil nutrient capital as a means of assessing the long-term productivity impacts in several forest ecosystems. The predictability of soil sensitivity to leaching will be greatly improved. Studies of the variability in the relationships among acid deposition, soil type, and aluminum mobility will be expanded.

Agricultural Crops. Future research will include more comprehensive analyses of possible impacts on crops including chemical composition of fruits and vegetables. Additional interaction studies, including fundamental research on physiological processes, will begin. A major effort will be made to screen crops for sensitive life cycles. More research on the possible impacts of acid deposition on sexual reproduction and fruit set will also start. A state-of-the-art assessment of dose-response relationships for corn and soybeans will be completed in 1984.

INTERRELATIONSHIPS

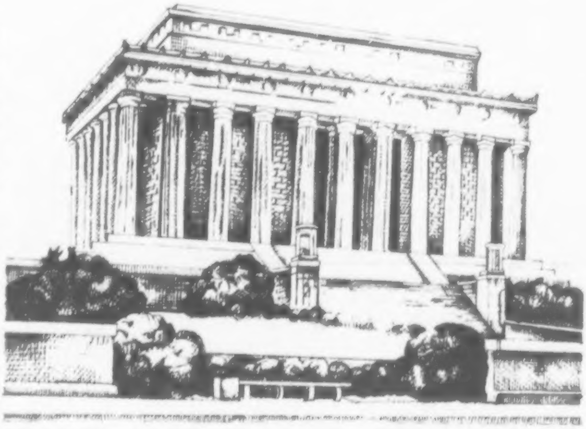
Coordination among task groups within the National Program and with other acid deposition research programs becomes critical as results begin to materialize. Close ties with the Assessments Task Group will be required if the National Program's primary responsibility is to be efficiently accomplished. The Terrestrial Effects Task Group is preparing for a major peer review during 1984.

Several activities directly affect the research being carried out under the Terrestrial Effects Task Group. For example, the Canadians, Germans, Swedes, and Norwegians are conducting major research on the terrestrial effects of acid deposition. Task group members are becoming familiar with this work through regular formal and informal scientific exchanges.

The National Science Foundation's Long-term Ecological Research Projects are contributing to our understanding of acid deposition effects. Major input is also expected from the EPRI Program and the National Atmospheric Deposition Program to help define research priorities.

G. *Effects on Materials and Cultural Resources*

BACKGROUND



Evidence in Europe and the United States indicates that air pollution significantly accelerates the weathering of materials and cultural resources, and reduces expected service. Damage to cultural resources may be irreversible. Both distant and local sources contribute to cumulative damage to materials. Susceptible materials, such as galvanized metals and marble, are used widely.

A major study by the National Bureau of Standards (NBS) estimated that in 1975 in the United States, the total cost of metallic corrosion was $70 billion. While only a portion of this can be related to air pollution, the annual cost of damage to metals and other materials that can be attributed to air pollution may be significant.

Damage to materials from acid deposition includes corrosion of metals, erosion and discoloration of paints, and decay of building stone and concrete — all of which also occur as a result of natural environmental conditions, even in unpolluted atmospheres. Moisture, carbon dioxide, sunlight, atmospheric oxygen, temperature fluctuations, and microorganisms all contribute to the deterioration of materials. Quantifying the specific contributions of man-made air pollutants such as acid deposition to such damage is a complex task.

It is important to differentiate between causes of material damage be they normal wear and tear, air pollution, or a specific component of air pollution. But the first need is to quantify damage. This is the task that occupies a large share of the resources of the Effects on Materials and Cultural Resources (Materials Effects) Task Group in the short term. An inventory of materials at risk is being compiled and analyses are underway to provide a picture of historical and contemporary materials damage. The specific role played by acid deposition will take time to unravel and at present remains a major uncertainty (see Table G-1).

Estimating the cost of materials damage is important for assessing the real cost of air pollution. Previous estimates of the materials damage costs related to pollutants are incomplete because:

1. Damages by various pollutants have not yet been reliably separated from each other and from natural agents, such as moisture and temperature.
2. Synergistic relationships between degradation agents are poorly understood.
3. Estimates of the quantities of materials exposed to acid deposition do not exist.
4. The way society chooses between continued use, repair, and replacement of materials has not been analyzed.
5. Damage to cultural resources has not been considered in the economic analyses.

Materials at risk include man-made materials such as metals and alloys, paint, plastics, brick and concrete, roofing and siding materials, and natural materials such as marble, limestone, granite, and calcareous sandstone. Inventories of the location and amounts of sensitive materials present in the geographic areas of concern do not exist. Such inventories must be completed if the economic effects of air pollution damage are to be assessed and comprehensive cost estimates developed.

Air pollutants directly affect materials by surface corrosion and secondarily by creating physical stresses that can alter the crystalline character of the material. It appears that dry deposition also causes significant damage during damp or humid conditions. Under humid conditions, the acids are released from dry deposits and degradation proceeds.

The principal air pollutants causing materials damage are sulfur oxides, nitrogen oxides, ozone, and particulate matter. In addition to attacking surfaces directly, the first two are precursors of particulate sulfates and nitrates that can travel long distances and, as acid deposition, create damaging effects many miles from the emission sources. Most materials, however, are located in urban areas where pollutants from local sources dominate.

Since pollutants are rarely encountered singly and are known to act synergistically, they must be examined in combination and in differing proportions corresponding to actual conditions in order to understand the full range of effects.

Some air pollution/materials damage information is available. For example, it is known that high humidity increases the rate of attack of sulfur dioxide on zinc, and that local variations in temperature also can be expected to influence damage rates. Wind velocity and direction can affect the deposition velocity and also promote surface abrasion by large airborne particles. An important role in materials damage also can be ascribed to special events such as dews, frosts, and fog in combination with acid deposition.

Chemical processes deteriorate masonry materials and cause metals, particularly aluminum and copper, to lose their protective coatings or patina. Over the

Table G–1. Summary of material damage from air pollution and other factors.

Material	Type of Impact	Principal Air Pollutants	Other Environmental Factors	Methods of Measurement	Mitigation Measures
Metals	Corrosion, tarnishing	Sulfur oxides and other acid gases	Moisture, air, salt, particulate matter	Weight loss after removal of corrosion products, reduced physical strength, change in surface characteristics	Surface plating or coating, replacement with corrosion-resistant material, removal to controlled environment.
Building Stone	Surface erosion, soiling, black crust formation	Sulfur oxides and other acid gases	Mechanical erosion, particulate matter, moisture, temperature fluctuations, salt, vibrations, carbon dioxide microorganisms	Weight loss of sample, surface reflectivity, measurement of dimensional changes, chemical analysis	Cleaning, impregnation with resins, removal to controlled environment.
Ceramics and Glass	Surface erosion, surface crust formation	Acid gases, especially, fluorides		Loss in surface reflectivity and light transmission, change in thickness, chemical analysis	Protective coatings, replacement with more resistant material, removal to controlled atmosphere.
Paints and Organic Coatings	Surface erosion discoloration, soiling	Sulfur oxides, hydrogen sulfide	Moisture, sunlight, ozone, particulate matter, mechanical erosion, microorganisms	Weight loss of exposed painted panels, surface reflectivity, thickness loss	Repainting, replacement with more resistant material
Paper	Embrittlement, discoloration	Sulfur oxides	Moisture, sunlight, physical wear, acidic materials introduced in manufacture	Decreased folding endurance, pH change, molecular weight measurement, tensile strength	Synthetic coating, removal to a controlled atmosphere, deacidification, encapsulation, impregnation with organic polymers
Photographic Materials	Microblemishes	Sulfur oxides	Particulate matter, moisture	Visual and microscopic examination	Removal to controlled atmosphere
Textiles	Reduced tensile strength, soiling	Sulfur and nitrogen oxides	Particulate matter, moisture, light, physical wear, washing	Reduced tensile strength, chemical analysis, surface reflectivity	Replacement, use of substitute materials, impregnation with polymers
Textile Dyes	Fading, color change	Nitrogen oxides, ozone	Sunlight, temperature	Reflectance and color value measurements	Replacements, use of substitute materials, removal to controlled environment.
Leather	Weakening, powdered surface	Sulfur oxides	Physical wear, residual acids introduced in manufacture	Loss in tensile strength, chemical analysis	Removal to a controlled atmosphere, consolidated with polymers, or replacement
Rubber	Cracking	Ozone	Sunlight, physical wear	Loss in elasticity and strength, measurement of crack frequency and depth	Add antioxidants to formulation, replace with more resistant materials

years, a considerable amount of industrial research has evaluated the relative susceptibilities of materials. More resistant materials have been developed, but little attention has been given to the precise role of air pollutants in materials damage.

RESEARCH GOALS AND ACTIVITIES

The National Program began assessing damage to materials and cultural resources by acid deposition in 1982. Several activities are underway to better understand and quantify the role of acid deposition in degrading various materials and cultural resources. Materials distribution and life cycle cost data bases are being assembled to support state-of-the-art acid deposition materials damage modeling. The Materials Effects Task Group has designed a research strategy that will facilitate basic understanding of damage mechanisms from which more accurate economic estimates can be made and from which effective protective measures for cultural materials can be developed.

Expected outputs from the materials effects research are performance data on materials in a range of environmental exposures, recommended maintenance cycles as a function of acid deposition levels for selected materials, and recommended mitigation strategies that can be applied in the private sector.

The Materials Effects Task Group's research strategy addresses five key questions:

1. What role does acid deposition play in materials degradation?

2. What is the rate of damage to specified materials as a function of acid deposition levels?

3. What is the geographic distribution of susceptible materials?

4. What is the appropriate economic value of materials damage?

5. What are appropriate protection and mitigation strategies?

PROGRAM ACCOMPLISHMENTS — FY 1983

FY 1983 was an active year for major program initiatives and innovation in this task group. Several agencies began to participate in effects on materials research: the National Mapping, Water Resources, and Geologic Divisions of the U.S. Geological Survey (USGS); the Corps of Engineers (COE) Cold Regions Research and Engineering Laboratory, Argonne National Laboratory, and the NBS's Center for Applied Mathematics. Canadian investigators began cooperating in the inventory and the field exposure programs. Coordination with the Assessments Task Group and the Acid Deposition Assessment Staff (ADAS) intensified.

1983 marks the second year of Materials Effects Task Group research and the first year of its deliverables. Significant outputs include publication of the *Bibliography of Effects of Acid Deposition on Corrosion and Deterioration of Materials 1880-1982.* This bibliography contains more than 1,300 articles, citations, and abstracts on the effects of acid deposition, air pollutants, and biological and meteorological factors on the corrosion and deterioration of materials in the atmosphere. The listing includes citations for the years 1950 to 1982, with selected citations for the years 1880 to 1949. The citations are catalogued by year in six sections for metallic materials: ferrous material, aluminum, copper, nickel, zinc and galvanized steel, and other metals; and six sections for nonmetallic materials: masonry, stone and ceramics, elastomers, fabrics, paints, plastics, and other nonmetals.

The results of a tombstone study, jointly supported by EPA and the National Park Service (NPS), were presented at the Air Pollution Control Association meeting in Atlanta in June 1983. This study compares the weathering rates for rural, suburban, and urban cemeteries with comparable climates and high annual precipitation, indicating that the urban environment causes significant damage beyond that observed in rural environments and tends to support the hypothesis that local pollution sources dominate the deposition of damaging pollutants.

Nineteen new research projects were begun in FY 1983, bringing current research activity to a total 28 projects. Highlights of ongoing and future research initiatives include:

Common Construction Materials Inventory. Estimates of the amount, kind, and a major location of building materials are required for the 1985 assessment. 1983 initiatives entailed research to design a spatial sampling scheme to provide a statistically valid approach to collecting field observations and for specifying allowable confidence and error limits in the final product. A pilot study to evaluate the inventory method using available field data, Census data, and USGS land use data is nearing completion. Implementation in the Northeast Region is scheduled for spring/summer 1984.

Distribution of Cultural Properties. A pilot study is underway to evaluate using Federal Historic Preservation data bases to derive surface area estimates of culturally important structures. In addition, a study of the feasibility of building a demographic model to estimate the distribution of outdoor sculpture was begun.

Life Cycle of Common Construction Materials. Research has begun to develop a method to measure the cost consequences of changes in durability and performance of exterior components of structures affected by acid deposition. This research will ultimately link inventory and damage function data bases to permit calculation of the costs of materials damage on a regional and national scale.

Chamber Studies of Materials Deterioration. Paints and metals are being exposed to fully characterized environments at ambient temperatures to study corrosion/erosion mechanisms. One complete diurnal moisture and light cycle is run every 6 hours and samples are sprayed with water of known pH and sulfuric and nitric acid concentrations to simulate rain events. A second research effort was begun to evaluate the performance of protective treatments for stone under controlled exposures of oxides of sulfur and nitrogen at ambient temperatures.

Field Exposure Program: Stone. Detailed research planning for exposing stone samples at the field sites began in earnest in FY 1983. Blocks of Indiana limestone and Vermont marble were quarried and are being characterized chemically and mineralogically. Specifications for sample preparation and exposure have been defined. Methods to measure stone deterioration, including chemical analysis of stone surface and runoff, petrographic analysis of mineral alteration, spectral analysis of surface recession and roughening, change in surface mechanical properties using ultrasonic sound waves, and calibration of gravimetric analysis for water and retained reaction products using Nuclear Magnetic Resonance spectroscopy have undergone preliminary testing. Field implementation was scheduled for March 1984.

Field Exposure Program: Metals. Atmospheric corrosion testing, coordinated with simultaneous meteorological, acid deposition, and air quality measurements, continues at four field sites to quantitatively correlate specific pollutants present in acid deposition with materials damage. The corrosion responses of seven metals are being evaluated over exposure cycles ranging from 1 month to 3 years. The result will be dose-response functions for these metals. Time-of-wetness sensors, exposed in both skyward and groundward positions, were installed for field evaluation at two of the four field sites (see Fig. G-1). Innovative approaches to sheltering samples to study wet and dry deposition effects separately were evaluated for field testing in FY 1984.

Derivation of Retrospective Damage Functions. Damage functions can be derived retrospectively by correlating available materials performance data with estimates of environmental conditions as determined from available monitoring data and modeling based on historic emissions. A project is continuing using trend analysis to identify significant subsets from the tombstone data and the materials performance data from commercial materials test sites. A site-specific air quality model will be applied to correlate these data and to derive damage functions for the 1985 Assessment.

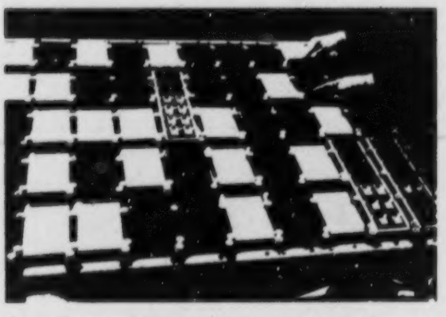


Figure G-1. Test stand showing assorted materials exposed to long-term weathering at Washington, D.C. (Smaller tiles are used for interim analysis.) Other test sites are at Research Triangle Park, N.C.; Chester, N.J.; and the Huntington Wildlife Forest, N.Y.

Methods for Monitoring Cultural Resource Deterioration. A series of projects to evaluate and refine measurement techniques for use in monitoring deterioration of cultural resources was begun:

1. Ultrasonic and eddy current methods to estimate pit depth and thickness of corrosion layers of bronze statues

2. A device to measure instantaneous corrosion rate of bronze statues

3. Near infrared spectroscopy to estimate concentrations of sulfate deposits on stone buildings and statues

4. Test kit for cultural resources managers to identify potential damage using low technology methods

5. Close range stereo photogrammetric recording and high precision polymeric casting methods to estimate material loss of sculpted surfaces at 5-year intervals.

FUTURE ACTIVITIES

Most of the research activities of the Materials Effects Task Group are long term. In addition to studies described in Program Accomplishments, work will continue in 1984 to produce the data bases required for the 1985 assessment. Specifically, efforts will focus on delivering an inventory of the Northeast of both cultural and common construction materials; delivering a data set of interim damage functions for metals, marble, and selected paints and coatings; and delivering life cycle cost data for major building components.

Research to improve the quality of future assessments is a basic part of the research strategy. Damage-function research will continue to be refined and expanded. Recommendations will be made for additional sites pending FY 1985 budget levels. The field exposure program will be expanded to include stone, concrete, and painted materials. Sheltering for samples will be installed at the field sites. The chemistry of particulate matter will be added to the environmental monitoring at the field sites, and a quality-assured aerometric data base management system implemented. Methods to estimate the economic value of irreplaceable cultural resources will begin to be developed.

INTERRELATIONSHIPS

This task group is coordinated by the NPS. Major projects involve the USGS, EPA, COE, Bureau of Mines, NBS, and Brookhaven and Argonne National Laboratories.

The task group is responding to the needs of other task groups of the Task Force in the following ways:

For the 1985 Assessment damage functions for sulfur dioxide for metals, marble, and selected coatings, an inventory of northeastern common construction materials and cultural properties and life cycle cost data will be supplied to the Assessments Task Group.

The Materials Effects Task Group participates in the Assessments Task Group's planning and coordination of research efforts with the Atmospheric Processes Task Group, with the Man-made Sources Task Group for historic emissions trends analysis, and with the Deposition Monitoring, Aquatic Effects, and Terrestrial Effects Task Groups for estimates of current deposition.

The task group intends to use present and past data on materials deterioration rates to calculate damage functions for commonly used materials such as construction metals, paints and coatings, and possibly unit masonry, by correlating these data with reconstructed air quality histories.

Other cooperative efforts include:

1. Investigation and mitigation methods for historic sites in Canada and the United States by Parks Canada, the Heritage Canada Foundation, and the U.S. National Capital Department of Public Works

2. Field exposure work being initiated by Environment Canada

3. Investigation of causes of damage to the Canadian Peterborough Petroglyphs

4. Florida Acid Deposition Study by the Florida Electric Power Coordinating Group, Inc.

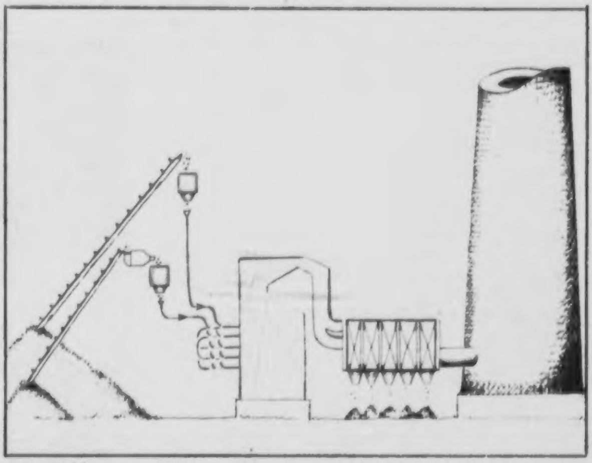
5. Materials damage investigation by the Western Energy Supply and Transmission Associates in the U.S. Southeast

6. Economic and retrospective investigations of the Electric Power Research Institute

7. California and Massachusetts studies in deterioration of bronze sculpture and other materials.

H. *Control Technologies*

BACKGROUND



A number of control technologies can reduce emissions of known acid deposition precursors from utility and industrial power generation and industrial processes. These technologies can be used alone or combined with nonhardware techniques to form a cost-effective control strategy. Any control strategy should strive for the most environmental protection possible for the cost. Design of such a cost-effective acid deposition control strategy depends on the mix of control technologies available and their cost and performance characteristics.

To date, federally-sponsored control technology research and development programs have primarily supported existing regulatory programs such as New Source Performance Standards and State Implementation Plans. The technology requirements for a cost-effective acid deposition regulatory program may differ significantly from past programs. For example, it is likely that reducing sulfur dioxide and nitrogen oxides emissions from stationary sources would focus on retrofitting controls to coal-fired utility and industrial boilers rather than simply controlling only new sources.

RESEARCH GOALS AND ACTIVITIES

The role of the Control Technologies Task Group is to provide the National Program with state-of-the-art information on all current and emerging technologies that may be employed in a wide variety of acid deposition control strategies. Specifically, task group objectives include the following:

1. To develop engineering cost and performance data for sulfur dioxide and nitrogen oxides control on fossil fuel combustion sources.

2. To evaluate technologies for control of acid deposition precursor emissions other than sulfur dioxide and nitrogen oxides.

3. To evaluate technologies for control of acid deposition precursor emissions from industrial processes.

Task Group members have assembled and adapted most of this data from federally-sponsored control technology programs outside the National Program, at Environmental Protection Agency (EPA), Department of Energy (DOE), and the Tennessee Valley Authority (TVA). Funding for the Control Technologies Task Group will begin in 1985. This will allow for special analyses of cost, performance, and applications data for technologies that reduce emissions of sulfur dioxide and nitrogen oxides. Because utility and industrial combustion of coal and industrial processes constitute the major sources of sulfur dioxide emissions, control technologies applicable to these stationary sources are of primary interest (see Table H-1).

In addition to providing state-of-the-art, cost, performance, and applicability data on existing control technologies for acid deposition precursors, the Control Technologies Task Group monitors Federal control technology research and development programs outside the National Program. Potential cost benefits of emerging control technologies thus can be properly assessed during policy analysis to evaluate the tradeoffs between relatively expensive existing control technologies and potentially more cost-effective developmental technologies. Up-to-date information on costs and performance of emerging control technologies is also useful in guiding Federal control technology research and development.

PROGRAM ACCOMPLISHMENTS — FY 1983

During FY 1983, the control technology research funded by EPA, DOE, and TVA made significant progress in developing improved methods for controlling sulfur dioxide and nitrogen oxides emissions. Although this research was funded outside the National Program, the Control Technologies Task Group has identified the following results as potentially relevant to the acid deposition issue:

Limestone Injection Multistage Burner (LIMB) Program. The significant progress made toward clarifying the mechanism of sulfur capture in furnaces has provided useful information for designing systems with more reactive sorbents (see Fig. H-1) and improved capture of sulfur dioxide by calcined limestones. This will improve capability to predict the effect of different design variables on LIMB performance. The current program is also beginning to provide data that will help us understand the possible effects of LIMB systems on furnace performance.

Flue Gas Cleanup Program. The technical feasibility of two dry regenerable processes for simultaneous control of both emissions was successfully demonstrated in small scale tests with high sulfur coal combustion gas. Both processes use alumina-supported sorbents in a fluidized-bed absorber. The sorbents tested were copper oxide with ammonia injection and sodium oxide.

Flue Gas Desulfurization (FGD) Program. Methods for improving the efficiency of existing TVA scrubbers were evaluated, including: (1) tests of the performance of several TVA area limestones containing soluble magnesium in both a nonoxidized and an oxidized mode; (2) tests of the effect of variable chloride concentrations in absorber slurries on sulfur dioxide removal efficiencies attainable with a conventional limestone-scrubbing system; and (3) initial planning for development of advanced scrubber designs for future use on the TVA system. In addition, operation of two pilot spray dryers was begun to determine the applicability of spray drying on flue gas generated from burning high sulfur coal. Installation of an electron-beam pilot plant designed for simultaneous removal of sulfur and nitrogen oxides was completed, with testing to begin in January 1984.

Sulfur Dioxide Emissions/Effluent Program. Documentation of the performance and cost advantages of the adipic acid enhanced limestone flue gas

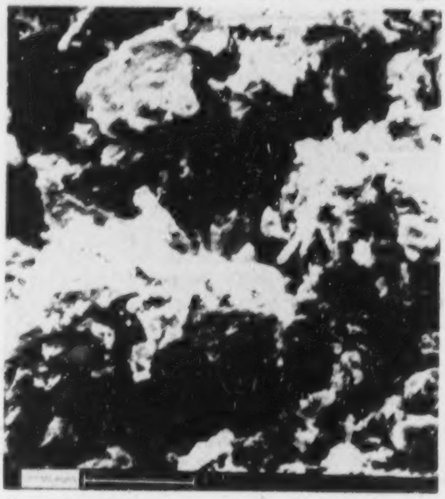


Figure H–1. Photomicrograph of limestone that has been specially treated to greatly increase surface area for better capture of sulfur dioxide.

Table H–1. Estimated costs of retrofit on coal-fired boilers

				Estimated Costs		
Technology	**Emission Reduction**	**Status**	**Applications**	**Capital Investment[2] ($/kW)**	**First Year Revenue (mills/kWh)**	**Cost Effectiveness ($/ton sulfur dioxide removed)**
Limestone Flue Gas Desulfurization (FGD)	90% Sulfur Dioxide Reduction	Commercial	Most large utility boilers; costs could sharply increase for difficult retrofits	200–370	10–19	460–870
Limestone FGD With Adipic Acid	90% Sulfur Dioxide Reduction	Early Commercial	Same as for conventional limestone FGD	180–330	9–17	400–760
Lime Spray Drying[3] (Dry Scrubbing)	70% Sulfur Dioxide Reduction	Early Commercial	Most experience with western coals; recently being applied to high sulfur coal applications	110–240	7–13	410–770
Limestone Injection Multistage Burners (LIMB)	50-60% Sulfur Dioxide Reduction 50-60% Nitrogen Oxides Reduction	Developmental	Demonstration cofunded by EPA and industry planned for 1986; effects on boiler and ESP performance unknown	30-80	3-7	230-490

1) Based on retrofit to 500 MW boiler firing 3.5 percent sulfur eastern bituminous coal; all costs expressed in 1983

2) Includes estimated capital investment for solid waste disposal facility

3) Cost and performance data for lime spray drying reflect estimates made for a system installed without a fabric filter, i.e., retrofitted upstream of the ESP on an existing boiler

desulfurization process was completed. The results show that this is now the most economical process for greater than 90 percent control of sulfur dioxide emissions from high sulfur coal applications. Field testing characterized the performance of full-scale spray dryer flue gas desulfurization systems on low sulfur coal applications. A joint government-industry workshop highlighted a new project to evaluate low cost, moderate removal flue gas desulfurization concepts. In addition, a program to evaluate the characteristics of full scale utility waste disposal sites was completed.

Nitrogen Oxides Combustion Modification Program. An advanced heavy oil burner developed for industrial boilers burning high nitrogen residual fuel oils has reduced nitrogen oxides emissions by about 85 percent from typical uncontrolled levels. Since this technology appears widely applicable to a range of industrial boilers and process combustors, it should be widely effective. The system improves nitrogen oxide reduction in oil-fired packaged boilers and systems that cofire fuel oils with highly nitrated industrial wastes.

Coal Preparation Program. The technical feasibility of using a true heavy liquid (freon) cyclone to significantly improve pyrite separation in fine-size coal cleaning devices was established. High gradient magnetic separation techniques are being evaluated for sulfur removal. Several advanced concepts for sulfur removal are being investigated: micro-bubble flotation, liquid carbon dioxide agglomeration, and microbial desulfurization among them.

FUTURE ACTIVITIES

The Control Technologies Task Group will continue to monitor control technology developmental activities of EPA, DOE, and TVA in FY 1984. In FY 1985, the task group will, for the first time, provide direct funding to conduct studies of specific control technology issues directly relevant to the acid deposition program.

Federal control technology research and development outside the National Program will focus on the development and demonstration of lower cost technologies of sulfur dioxide, nitrogen oxides, and particulates from coal-fired power generation in FY 1984.

Limestone Injection Multistage Burner Program. During FY 1984, recently determined techniques to generate high surface area limestone will be scaled up to produce sufficient quantities for large pilot tests. Also, coal cleaning will be evaluated as a means of preventing sorbent deactivation since alumina and silica compounds, which are present in coal ash, have been found to interfere with sorbent reactivity. Coal cleaning will also be evaluated for its potential to minimize the effects of increased particle loading on performance of existing electrostatic precipitators (ESPs) for retrofit applications. Additionally, ESP design modifications are being explored as a means of handling the increased loading from injection of limestone.

Flue Gas Cleanup. Primary emphasis in FY 1984 will be on determining the technical feasibility of electron beam radiation to enhance sulfur and nitrogen oxides capture in flue gas cleanup processes. Two processes will be evaluated; the first, located at TVA's Shawnee Plant, uses a lime spray dryer in conjunction with the electron beam. The second, located at Indianapolis Power and Light's E. W. Stout Plant, uses ammonia injection in conjunction with the electron beam. Performance goals for both processes are 90 percent removal of both sulfur and nitrogen oxides.

Flue Gas Desulfurization Program. In FY 1984, TVA will continue to explore the combined benefits of reducing the sulfur in coal and developing better postcombustion FGD and simultaneous nitrogen and sulfur oxides removal processes.

Sulfur Dioxide Emissions/Effluent Program. The core of EPA's program will be a continuation of efforts to assess developments, commercialize new technologies, and transfer results of these assessments to the user community. The assessment efforts will be supported by an in-house FGD pilot plant testing program. A new initiative will focus on operations research for optimizing integrated emissions reduction technologies. Emphasis will be on defining the optimal performance at minimal costs for combinations of technologies such as coal cleaning, LIMB, dry sorbent injection, spray drying, and dry particle control devices.

Nitrogen Oxides Combustion Modification Program. Emphasis in this program will be on the field evaluation of a heavy oil-low nitrogen oxide burner for industrial boilers and on assessing advanced in-furnace nitrogen oxide reduction (reburning) technology for use in boilers and industrial process combustors. A project will be initiated to evaluate the application of an adapted commercial burner design for nitrogen oxide reduction in industrial package boilers and for co-firing of fuel oil and highly nitrated waste fuels. In-furnace nitrogen oxide reduction, a technology that provides secondary fuel injection beyond the primary combustion zone to reduce most of the nitrogen oxides to molecular nitrogen, will continue to be investigated. Tests will be performed to evaluate this technology for oil- and coal-fired boilers and for refinery process heaters. Limited testing will be completed of a selective catalytic reduction system applied to natural gas spark ignition engine for nitrogen oxide control.

Coal Cleaning. In FY 1984, DOE will continue researching advanced coal cleaning systems targeted at applying physical and/or chemical processes to remove sulfur (organic and pyritic) and ash forming mineral matter from coal. A significant part of the effort is the development of fine coal cleaning technology that could more efficiently and economically remove pyritic sulfur and ash from coal. If these technologies were applied to fuel supplies of existing coal-fired power plants, sulfur dioxide could be reduced significantly.

INTERRELATIONSHIPS

The major activity of the Control Technologies Task Group to date has been to monitor the control technology developmental activities of EPA, DOE, and TVA. This is achieved by periodic technology transfer among the involved parties at each organization. The director of EPA's Industrial Environmental Research Laboratory in Research Triangle Park (IERL/RTP), N.C., is chairman of the Control Technologies Task Group. Program and budget planning, project implementation, and project review and evaluation are coordinated by management and staff at IERL/RTP with support from DOE and TVA personnel. Within the National Program, the task group has direct linkages to the Man-made Sources Task Group and the Assessments Task Group to ensure that the performance and costs of control techniques are accurately addressed in emission projections and control strategy assessment activities.

The task group stays abreast of control technology activities conducted outside the Federal program. The most important activities in this regard are coordination with the Electric Power Research Institute (EPRI) and the Utility Air Regulatory Group. The connection is maintained though formal and informal information exchange programs with the task group's member organizations. This includes several jointly sponsored symposia on control technologies such as the Symposium on Flue Gas Desulfurization. In addition, a Memorandum of Agreement is being finalized to coordinate EPA and EPRI's programs in the LIMB area.

The task group also follows control technology developments in other countries. This includes formal agreements with the Canadians, Japanese, and Germans in addition to participation in NATO-Critical Challenges to Modern Society activities. Of particular relevance are the low nitrogen oxide burner and FGD applications in Japan and LIMB developments in Germany.

The Control Technologies Task Group's program to monitor control technology developmental activities at EPA, DOE, and TVA will soon be augmented by special studies to relate important results directly to acid deposition issues. These studies will incorporate research findings from private industry and government in the United States and other countries. Outputs from the program will define the performance and costs of alternative emission control techniques to ensure that sound decisions can be made on acid deposition control strategies.

I. *Assessments*

BACKGROUND

Estimating how much overall damage acid deposition has caused requires a careful assessment of scientific knowledge. As a beginning, the Assessments Task Group prepared the 1983 "Critical Assessment Review Papers" to bridge the gap between published and ongoing research. From this baseline work and the results of ongoing research, future integrative assessments will be performed. These are difficult to do now because the gaps in knowledge are wide, the uncertainties numerous, and our experience in such endeavors is extremely limited. The state of the science, which allows healthy but abundant contradiction of scientific hypotheses, probably will not yield a scientifically complete assessment of acid deposition in the next few years.

The Assessments Task Group is analyzing the range of complex scientific interactions for the 1985 Assessment. To date the state of the science will not allow assertive recommendations. Trends are weak and evasive. Data are spotty. As more data are generated by the Task Force and others the uncertainties can be reduced.

Significant uncertainties still face the Assessments Task Group. One of the most basic is the extent of damage caused by acid deposition and its rate of change. During FY 1983 two studies done outside the Task Force have unveiled some other basic uncertainties.

A study by a National Academy of Sciences/National Research Council Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation generated much debate when it concluded that there is "no evidence for a strong nonlinearity in the relationships between long-term average emissions and deposition," but that there is not sufficient scientific confidence in the ability of currently available models to relate specific emissions at specific sources, local or distant, to acid deposition at other sites.

A study by a committee of the President's Office of Science and Technology Policy, reviewing the scientific documents prepared under the United States-Canada Memorandum of Intent on Transboundary Air Pollution, recognized a range of uncertainties but recommended in a brief preliminary report that some immediate action be taken to control acid deposition because of the possibility of "irreversible" effects.

These two reports, and others published during the year, emphasize the concern about acid deposition and its impacts and the need to reduce rapidly the uncertainties regarding the phenomenon.

RESEARCH GOALS AND ACTIVITIES

The goals of the assessments research program are to build upon earlier studies and draw from existing analytical methods to construct the means for comprehensive benefit-cost assessments. This capability will be unique in at least two ways. First, it will be designed to deal quantitatively with the range of uncertainty around various data and their use. In addition to organizing scientific results, the research program will ensure that the National Program can produce information that is relevant to decisionmaking.

The Task Force has defined the scope of the major assessment in FY 1985 to encompass four areas: (1) an assessment of current damages attributable to acid deposition; (2) an uncertainty analysis of key scientific areas, especially emissions and atmospheric processes; (3) the implications of uncertainty in these areas on policy alternatives; and (4) a description of the framework for the integrated assessment methodology that will be the basis of the 1987 and 1989 integrated assessments.

More comprehensive assessments based on an integrated framework that combines emissions models, source-receptor relationships, and dose-response functions will be possible in 1987 and 1989. At present, much of the basic information for these assessments is unavailable but research projects within the National Program are vigorously pursuing the information, including estimates of the benefits and associated costs of alternative control and mitigation measures.

By applying cost-benefit assessments and special studies as needed, the Assessment Task Group expects to answer the following key questions:

1. What is the physical, biological significance of current and expected adverse or beneficial effects from the deposition of acidic and acidifying materials in North America?

2. How are the composition and distribution of acid deposition in North America linked with emission patterns, and what significance do uncertainties have for control or mitigation strategies?

3. From what range of strategies for integrated emission control and receptor-oriented mitigation can policymakers choose?

4. Which strategies show the greatest promise of cost effectiveness and what bounds of uncertainty should be placed around such conclusions?

5. What specific research would most effectively reduce the physical, biological, and economic uncertainties that decisionmakers must face in choosing among strategy options for dealing with acid deposition?

To address these questions the Assessments Task Group's program has organized its research activities into three areas. The first is methods development that focuses on providing the basic tools for conducting future integrated assessments in five subject areas: economic, effects, source-receptor, control/mitigation strategy, and integrated assessment.

The second area is that of coordination and integration. This covers the activities of the Acid Deposition Assessment Staff (ADAS) and assessment data base coordination, implementation, and management.

The third area, application, uses assessment methods on the research findings of participating task groups to produce special scientific technical assessments and the major assessment documents mandated by Congress. Table I-1 outlines the overall research plan.

PROGRAM ACCOMPLISHMENTS — FY 1983

During FY 1983 the Assessments Task Group's research plan was refined and implemented. ADAS was formed through a memorandum of agreement between the Envionrmental Protection Agency (EPA) and Department of Energy (DOE) as the operational arm of the Assessments Task Group. This staff leads the research program of the Assessments Task Group and helps focus the broader National Program on assessment goals. Accomplishments for this year are organized by the three main research areas.

Methods Development

Advanced Utility Simulation Model. A preliminary version of the Advanced Utility Simulatión Model (AUSM) was transferred from the model developers to the EPA computer and operated within the Integrated Emissions Strategy Modeling Project. The model development project is supported by the Man-made Sources Task Group, and the integration effort is jointly sponsored by the Man-made Sources and Assessments Task Groups. This was an early successful test of the concept of a model developed in one task group and subsequently incorporated into an integrated framework of another. This concept is critical to the Integrated Assessment Methodology.

Integrated Assessment Methodology. A key goal in FY 1983 was to develop a methodology for the 1987 and 1989 integrated assessments of acid deposition. This activity took form as two closely related but independent research projects.

The first drew on the expertise of the four National Laboratories in the National Laboratory Consortium (NLC). By taking a systems approach to integrating the many facets of acid deposition, the NLC has determined that acid precursors are emitted, transported, transformed, and deposited on the surface; move through various ecosystems; and interact with those ecosystems. These interactions result in physical and economic impacts that may influence policy decisions. Changes in policy may lead to changes in emissions which then affect the entire analytical system.

Each of these processes is associated with a model (node) that describes mathematically what that process does. The definition of processes that occur at each of these nodes also serves to identify the information transfers required to let each process model function. The NLC has laid out the process nodes, data linkages, and processes required for an integrated assessment and a draft report is anticipated in FY 1984.

The second, under provisions of a cooperative agreement between EPA and North Carolina State University, resulted in a competitive award late in FY 1983 to Carnegie-Mellon University for development of a trial framework for integrated assessment.

The Carnegie-Mellon University and NLC activities will continue in FY 1984 with further definition and testing of the models and data exchanges needed to unify the system.

Uncertainty Analysis. A preliminary evaluation of uncertainties in predicting acid deposition and its ef-

Table I—1. Outline of research plan for Assessments Task Group

Integrated Assessment Methods Development
Develop economic benefits assessment methods
Develop advanced effects assessment methods
Develop advanced methods for source/receptor assessment
Develop integrated emissions control and mitigation strategy Analysis methods
Develop advanced methods for integrated assessment
Integrated Assessment Coordination and Integration
Coordinate Task Group I activities
Develop and implement assessment data base system
Develop policy focus for assessment activities
Integrated Assessment Applications
Perform and participate in special scientific/technical assessments
Apply advanced integrated assessment methods

fects was completed by Argonne National Laboratory and is being reviewed. The study focused on uncertainties in estimating emissions, atmospheric transport and deposition processes, and lake acidification. Also, a preliminary analysis of methods for estimating uncertainty in source-receptor relationships was conducted in the last several months of FY 1983 to serve as planning information for conducting the uncertainty analysis in the 1985 Assessment. Based on the findings of this analysis, a program is underway to assemble the required models and carry out computations during FY84 and FY85.

Coordination and Integration

Acid Deposition Assessment Staff. ADAS is a group of professionals drawn from EPA, DOE, and DOE National Laboratories, each with experience in various aspects of the acid precipitation phenomenon. ADAS provided leadership in the following areas:

1. Planning and preparation of the 1985, 1987, and 1989 Assessments

2. Revision and refinement of the National Program operating plan for the Assessments Task Group

3. Defining the scope of the Assessments Task Group's research program and preparing project descriptors

4. Structuring the FY 1984 and FY 1985 research and budget plans for the Assessments Task Group

5. Preparing an oversight report for the National Program.

1985 Assessment. A draft report outline and several draft frameworks were distributed by the Assessments Task Group for comment. The purpose of these drafts was to define the content of the 1985 Assessment and to establish the basis for coordinating information transfers from other task groups into the assessment program.

Figure I-1 shows the information flow for the current damage assessment component of the FY 1985 Assessment. The deposition information, inventories of sensitive resources, and dose-response information are produced by various technical components of the National Program and combined to produce an estimate of the magnitude of physical damages. The Assessments Task Group is working toward a detailed accounting of economic damages.

Data Coordination. The anticipated data needs of the Assessments Task Group and other task groups are such that every task group within the National Program exchanges data. Early in FY 1983 Brookhaven National Laboratory and Oak Ridge National Laboratory (ORNL) developed a data coordination plan. To implement this plan an Assessments Task Group data coordinator has begun identifying the data exchanges needed for the 1985 Assessment report.

Statistical Evaluation. A committee from the American Statistical Association will set up a statistical

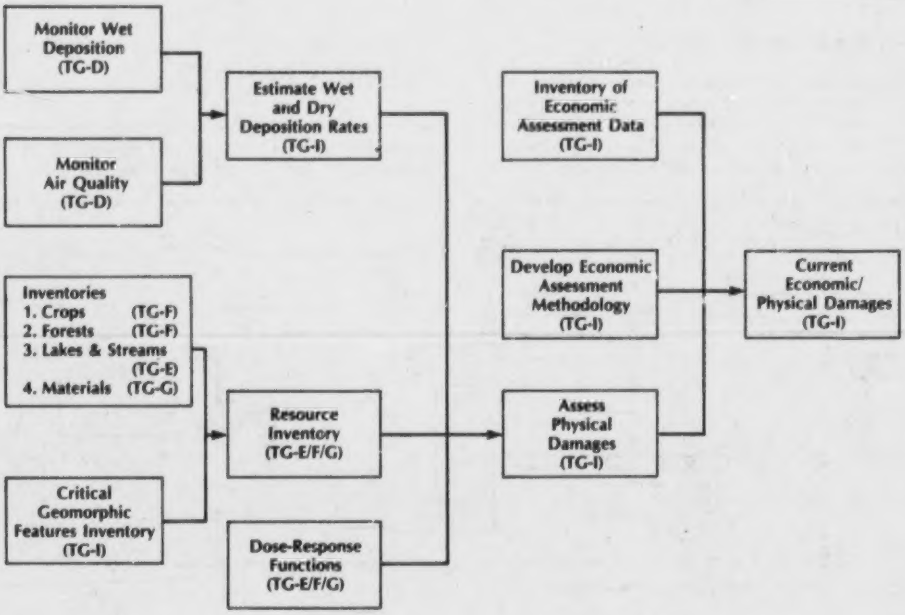

Monitor Wet Deposition (TG-D)
Monitor Air Quality (TG-D)
Estimate Wet and Dry Deposition Rates (TG-I)
Inventories
1. Crops (TG-F)
2. Forests (TG-F)
3. Lakes & Streams (TG-E)
4. Materials (TG-G)
Critical Geomorphic Features Inventory (TG-I)
Resource Inventory (TG-E/F/G)
Dose-Response Functions (TG-E/F/G)
Inventory of Economic Assessment Data (TG-I)
Develop Economic Assessment Methodology (TG-I)
Assess Physical Damages (TG-I)
Current Economic/ Physical Damages (TG-I)

Figure I–1. 1985 Assessment by task group evaluation of several major projects particularly important to the 1985 Assessment.

Acid Precipitation Research Inventory. The content of an acid precipitation research inventory was established, and the inventory, maintained by ORNL for the National Program, is now on line and provides direct access by the Task Force.

Application

Critical Assessment Review Papers. Three thousand copies of the draft, "The Acidic Deposition Phemonomen and Its Effects: Critical Assessment Review Papers," were printed and distributed for public comment in June 1983. Fifty-three reviewers returned 130 sets of comments during the 45-day public comment. These comments will go into a final revision of the document and a summary Critical Assessment Review Paper. Many areas of uncertainty were emphasized by commenters.

FUTURE ACTIVITIES

FY 1984 is a pivotal year in the production of the 1985 Assessment and the establishment of methods for use in the 1987 Assessment. Assessment data will be compiled within the Acid Deposition Data Network and analyses will begin for the 1985 report.

Highlights of plans for the four major research areas follow:

Methods Development

Integrated Emissions Modeling System. Integration and testing of the integrated emissions modeling system to be used in the 1985 Assessment will be completed. This system will include baseline energy/economic scenarios, the State-level AUSM, the prototype Industrial Combustion Emissions (ICE) Model, the Emissions Strategy Integration Model, and results of scoping analyses for other relevant sectors.

Source-Receptor Uncertainty Analysis. The program planning for source-receptor uncertainty analysis will be completed in FY 1984. Estimates of the effects of several key atmospheric processes under a mix of meteorological conditions will be computed. An historical reference of the climatology versus the source-receptor relationships for eastern North America will also be computed from an existing Lagrangian model. This climatology reference will also support the forestry and materials damage assessments.

Economic Benefits. Preliminary economic analyses will begin in each affected area. These analyses include the development testing and application of a model to estimate the benefits resulting from reduced acid deposition and improved sport fishing in the Adirondacks. The economic data and inventory of lake characteristics are being collected for the 1985 Assessment.

Integrated Assessment Methodology Development. The integrated assessment methodology development projects will be evaluated in detail at a workshop in 1984. Recommendations from that workshop will result in a unified activity leading to a prototype methodology to be tested in FY 1985 for the 1987 Assessment.

Figure I-2 illustrates the framework for improving information and models of atmospheric processes and similarly improving the way analyses of ecosystems and effects come together to compare costs and benefits of alternative policies. The key parts of this framework should be available in 1986.

INTERRELATIONSHIPS

The Assessments Task Group is responsible for incorporating the results of all the task groups' projects and studies into the Task Force's assessment products.

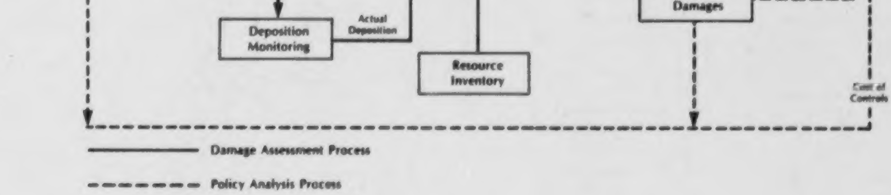

Emissions Inventory
Dose-Response Functions
Mitigation Models
Emissions Forecast
Deposition Forecast
Modified Response
Cost of Mitigation
Control/Mitigation
Emissions Models
Atmospheric Models
Receptor Area Models
Physical Damages
Policy Evaluation and Selection
Projections Trends
Value of Benefits
Economic Damages
Actual Deposition
Deposition Monitoring
Resource Inventory
Cost of Controls
Damage Assessment Process
Policy Analysis Process

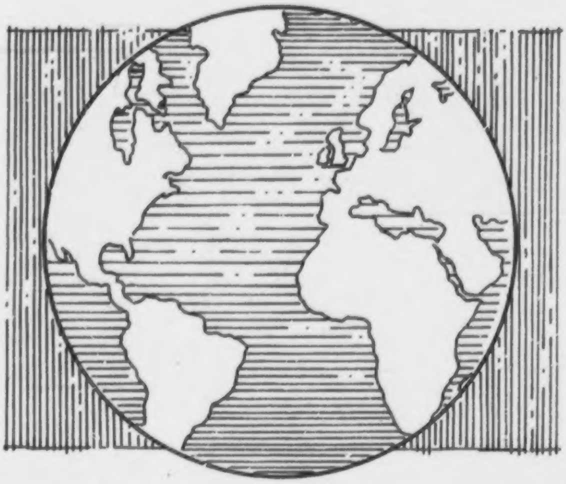
Figure I-2. Integrated assessment process 1987 and beyond

The Electric Power Research Institute has funded decision analysis methods development for acid deposition, and individual National Science Foundation-funded researchers have applied their methods in this area.

The International Activities Task Group provides a mechanism to conduct joint projects with other Nations including the Canadian government. Several bilateral acid deposition research projects are currently underway between the United States and Canada, and more projects have been proposed. Also, a small, joint scientific effort involving United States and West German scientists was recently funded by the Assessments Task Group.

J. International Activities

BACKGROUND



The goal of the Task Force's International Activities Task Group, chaired by the Department of State, is to encourage international cooperation on acid deposition research and monitoring. The Acid Precipitation Act of 1980 (Title VII of P.L. 96-294) requires the Task Force to coordinate the National Program appropriately with similar research performed in other countries.

Transboundary air pollution is of widespread international concern. The U.N. Conference on Human Environment in Stockholm in 1972 led to realization of the need to address transboundary air quality degradation and to study potential acid deposition impacts. Ten years later, in 1982, technical experts and government officials held a review meeting in Sweden to exchange information on acid deposition pollutants and effects.

The U.N. Economic Commission for Europe (ECE) in 1971 established a permanent ECE Subsidiary Body, the Senior Advisors to ECE Governments on Environmental Problems (SAEP). The United States is a member of both groups.

In 1978 the SAEP prepared recommendations for dealing with long-range transboundary air pollution. The ECE adopted the SAEP's draft convention and adopted and opened for signature the present ECE Convention on Long-range Transboundary Air Pollution. Delegates representing 33 member States of the ECE, plus four non-ECE States and 24 international governmental and nongovernmental organizations participated. Interim technical development activities took place after the Convention was signed.

A principal activity under the Convention is the periodic review of national experiences, strategies, and policies in dealing with air pollution, including acid deposition. These activities emphasize the control of sulfur dioxide emissions. Voluntary cooperation under the Convention is also to take place with regard to nitrogen oxides, specifically information gathering and research activities. Another important activity is the Cooperative Program for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (known as EMEP), which cooperates with the North American monitoring program.

The concern of the United States and Canada with international air pollution led to the signing of a Memorandum of Intent (MOI) in August 1980 to negotiate a transboundary air pollution agreement. To assist in the negotiations, joint technical Work Groups compiled relevant data on the long-range transport of air pollution, with major emphasis on acid deposition. By early 1983 these joint Work Groups completed their final reports. Separate U.S. and Canadian peer review panels had been established and reviewed the Work Group Reports in 1983 (see Fig. j-1).

Although the MOI Work Groups and the Task Force are two different entities with distinct functions, many of the same U.S. scientists contributed to both efforts. The role of the bilateral Work Groups was to establish a mutually-agreed-upon technical basis supporting the MOI negotiations; the Work Groups in this respect were significantly successful although some genuine disagreement was evident between U.S. and Canadian scientists with regard to the interpretation of data, particularly those on aquatic effects.

RESEARCH GOALS AND ACTIVITIES

The International Activities Task Group's goals are:

1. Encourage and facilitate productive interaction between the National Program and other Nations conducting acid deposition research and monitoring activities.

2. Assist the Task Force and its Research Coordination Council in tracking international cooperative efforts.

3. Recommend to the Task Force ways to improve international cooperation and identify opportunities to

work with other Nations toward common research goals.

4. Inform the Task Force of activities, meetings, and developments in other Nations.

PROGRAM ACCOMPLISHMENTS — FY 1983

The most significant accomplishment of the task group in 1983 was the Task Force's identification of a series of U.S. cooperative acid deposition research projects with Canada. The Task Force and its Canadian counterpart, the Federal-Provincial Research and Monitoring Coordinating Committee (RMCC), met in April 1982 and agreed to develop a two-way flow of proposals for cooperative research. During 1982 and early 1983 the International Activities Task Group, with the cooperation of and advice from the other task groups, worked to identify a variety of ongoing and possible cooperative research projects.

Parallel project identification work proceeded in Canada, and in July 1983 the Task Force and RMCC met and jointly identified 12 existing projects and approved 21 proposed projects for further consideration as new cooperative research efforts. Steps were also taken to enhance coordination of the quality assurance components of the Task Force's and RMCC's ongoing research.

INTERNATIONAL ACTIVITIES

Task group members spent the remainder of 1983 conferring with the other task groups about proposed projects in terms of their priorities, the budget cycle, appropriate working-level contacts between scientists of both countries, and how to track developments by appropriate task group leaders. A follow-up meeting of the Task Force and RMCC is scheduled for May 1984.

Figure J–1. Joint United States-Canadian monitoring site near Lake Superior. U.S. collector is on the left in the foreground.

The International Activities Task Group also arranged for increased U.S. voluntary support of the EMEP air pollution monitoring and evaluation program. At the first full meeting of the executive body to the ECE Convention, the United States was a major participant in developing a work plan designed to produce technical results for executive body use. This plan includes revision of acid deposition effects reports and development of cost-benefit techniques to be applied using each country's emissions data bases and control plans.

FUTURE ACTIVITIES

The United States will continue to be involved as a contracting party in activities under the ECE Convention on Long-Range Transboundary Air Pollution. The second meeting of the executive body of the Convention will be in September 1984 and will review national policies and strategies in dealing with air pollution.

During 1984 significant research on the various U.S.-Canada cooperative acid precipitation projects will continue. In addition, it appears likely that information exchange and possibly some cooperative projects on acid precipitation research will be increased with the European Community. Exploratory discussions are underway and will be expanded next year with the Federal Republic of Germany designed to develop a bilateral acid deposition effects cooperative research program within the context of the current U.S.-FRG Environmental Agreement. Preliminary site visits by U.S. scientists to FRG research projects and reciprocal visits by West German researchers to U.S. monitoring and effects research sites will take place in summer 1984. As a participant in the Organization for Economic Cooperation and Development Environment Committee, the United States will help with its work on pollutants, including oxidants and acid rain precursor pollutants. The Task Force will be involved in all of these activities.

INTERRELATIONSHIPS

The International Activities Task Group meets several times during the year to discuss ongoing and potential opportunities for scientific cooperation between the National Program and other Nations. The task group also keeps a schedule of the international conferences and workshops relevant to acid deposition to ensure continued participation by all interested members of the Task Force. This information is shared freely among all the task groups of the National Program.

The Task Force and the RMCC have developed a two-way flow of proposals for cooperative research. Under the National Program, the International Activities Task Group works closely with the other task groups and agency representatives to identify research projects for possible international coordination. When the Task Force's Research Coordination Council (RCC) reviews all proposed bilateral projects, they consider research objectives; linkages with other research and monitoring activities in the United States and abroad; establishment of working-level contacts between scientists of both countries; and methods available for program managers to track research development.

Key to Acronyms

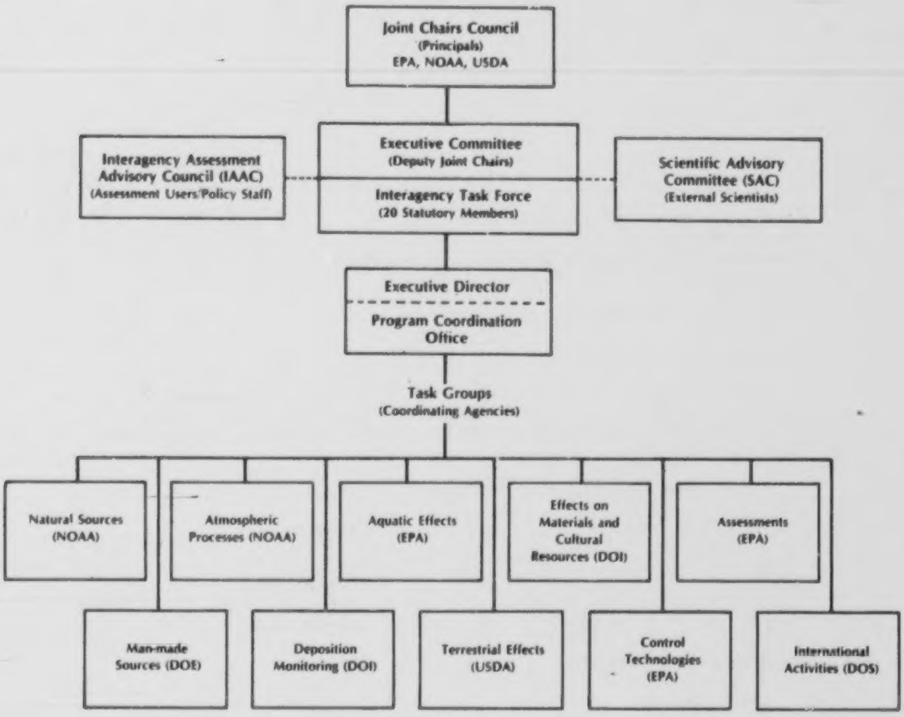
ADS	Acid Deposition System
ASTRAP	Advanced Statistical Trajectory Regional Air Pollution Model
ADAS	Acid Deposition Assessment Staff
AUSM	Advanced Utility Simulation Model
CANSAP	Canadian Network for Sampling Precipitation
CAPMON	Canadian Air and Precipitation Monitoring Network
CAPTEX	Cross Appalachian Tracer Experiment
CEQ	Council on Environmental Quality
DOC	Department of Commerce
DOE	Department of Energy
DOI	Department of Interior
DOS	Department of State
ECE	Economic Commission for Europe
EMEP	Cooperative Program for Monitoring and Evaluation of Long-Range Transmission of Air Pollutants in Europe
ENAMAP	Eastern North American Model of Air Pollution
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
FRG	Federal Republic of Germany
FS	Forest Service
FWS	Fish and Wildlife Service
FY	Fiscal Year (Oct. 1 through Sept. 30)
GTN	Global Trends Network
HHS	Health and Human Services
ICE	Industrial Combustion Emissions Model
ILWAS	Integrated Lake Watershed Acidification Study
LIMB	Limestone Injection Multistage Burner
MAP3S	Multi-State Atmospheric Power Production Pollution Study
MOI	Memorandum of Intent
NADP	National Acid Deposition Program
NAPAP	National Acid Precipitation Assessment Program
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NBS	National Bureau of Standards
NCA	National Coal Association
NCAR	National Center for Atmospheric Research
NLC	National Laboratory Consortium
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NSF	National Science Foundation
OECD	Organization for Economic Cooperation and Development
ORNL	Oak Ridge National Laboratory
OSCAR	Oxidation and Scavenging Characteristics of April Rains
PCO	Program Coordination Office
PNL	Pacific Northwest National Laboratory
RADM	Regional Acid Deposition Model
RCC	Research Coordination Council
RMCC	(Canadian) Federal/Provincial Research and Monitoring Coordinating Committee
SAEP	Senior Advisors to ECE Governments on Environmental Problems
SE	Science and Education (USDA)
STEM	Sulfur Transport Eulerian Model
SURE	Sulfur Regional Experiment
TVA	Tennessee Valley Authority
UAPSP	Utility Acid Precipitation Study Program
UN/ECE	United Nations Economic Commission for Europe
USDA	United States Department of Agriculture
USGS	United States Geological Survey

Schedule of Activities

Schedule of FY 1983 National Program Activities

12/15/82	Research Coordination Council (RCC) Meeting	FY 1984 budget passback from OMB, review of initial drafts of FY 1982 Annual Report, report on Federal/State/private sector coordination
2/20-25/83	Peer Review	Peer review of National Program's aquatic and terrestrial effects research
3/30/83	Task Force Meeting	Introduction of presidential appointees to Task Force, timetable for completion of Operating Research Plan and FY 1985 budget process
4/5/83	Program Management Review	Task Force review of status and progress of aquatic and terrestrial effects research
4/15/83	Program Management Review	Task Force review of status and progress of sources and control technologies research
4/16/83	RCC Meeting	Initial plans for 1983 Annual Meeting, preliminary OMB guidance for FY 1985 budget, schedules for completion of Task Force budget submission and completion of Operating Research Plan, status reports on projects inventory and data management study
4/19/83	Program Management Review	Task Force review of status and progress of materials effects and assessments research
6/8/83	Press Briefing	Public release of Task Force's FY 1982 Annual Report to the President and Congress
7/6/83	Task Force Meeting	Status of Operating Research Plan, review of Task Groups' revised FY 1985 budget proposals
7/11-13/83	U.S./Canada Research Coordination Meeting	Met with the Canadian Research and Monitoring Coordinating Committee (RMCC) to expand bilateral cooperation on current and proposed acid precipitation research projects in a number of areas
8/8-12/83	Peer Review	Peer review of National Program's man-made and natural sources, atmospheric processes, and deposition monitoring research
9/20/83	RCC Meeting	Status of current task group activities, preparation for upcoming ad hoc review panel presentations, review of FY 1985 revised budget submission, report on recent peer review of ongoing research

ORGANIZATION CHART OF THE NATIONAL ACID PRECIPITATION ASSESSMENT PROGRAM


Joint Chairs Council
(Principals)
EPA, NOAA, USDA
Interagency Assessment Advisory Council (IAAC)
(Assessment Users/Policy Staff)
Executive Committee
(Deputy Joint Chairs)
Interagency Task Force
(20 Statutory Members)
Scientific Advisory Committee (SAC)
(External Scientists)
Executive Director
Program Coordination Office
Task Groups
(Coordinating Agencies)
Natural Sources (NOAA)
Man-made Sources (DOE)
Atmospheric Processes (NOAA)
Deposition Monitoring (DOI)
Aquatic Effects (EPA)
Terrestrial Effects (USDA)
Effects on Materials and Cultural Resources (DOI)
Control Technologies (EPA)
Assessments (EPA)
International Activities (DOS)

Richard

NATIONAL RESEARCH COUNCIL

COMMISSION ON PHYSICAL SCIENCES, MATHEMATICS, AND RESOURCES

2101 Constitution Avenue Washington, D.C. 20418

ENVIRONMENTAL STUDIES BOARD

Official Committee File

May 22, 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
MAY 25 1984
WASHINGTON, D.C. 20510

Honorable James A. McClure
United States Senate
Committee on Energy and Natural Resources
Washington, D.C. 20510

Attention: Richard D. Grundy

Dear Senator McClure:

Raphael Kasper has asked me to provide answers to the questions submitted in your letter to him of May 10, 1984. The questions were raised as a result of his testimony before the Committee on April 30.

The answers are enclosed.

Sincerely,

Myron F. Uman
Myron F. Uman
Staff Director

cc: Raphael G. Kasper
Paul L. Sitton
Jack Calvert

The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering to serve government and other organizations

Response to Questions Submitted to Dr. Raphael Kasper
by the
Committee on Energy and Natural Resources

Oversight Hearing
on the Implementation of
the Acid Precipitation Act of 1980

1. Did the National Academy report conclude that a 50% reduction in sulfur dioxide emissions in the Midwest would result in a 50% or nearly 50% reduction in acid deposition in the northeast United States?

   No. The report concluded that a 50 percent reduction in sulfur dioxide emissions throughout a large region of eastern North America, including the Midwest, Northeast, and eastern Canada, would result in a similar reduction in deposition of sulfuric acid throughout the whole region. A 50 percent reduction of emissions in the Midwest will not guarantee a 50 percent in deposition in the Northeast because other regions of the U. S. and Canada, including the Northeast, also contribute to deposition in the Northeast. The conclusion of the report pertains to emissions of sulfur dioxide and deposition of sulfuric acid, which accounts for about two-thirds of the total acidity in precipitation.

2. Is this conclusion different from the conclusion of the 1981 Academy report? If so, on the basis of what new scientific evidence was this different conclusion reached?

   The 1981 Academy report did not address this issue but instead focussed on ecological effects of acid deposition as well as other pollutants associated with fossil fuel combustion.

3. Did the National Academy conclude that acid precursor emissions closer to the sensitive areas of the eastern United States will have a greater impact on acid deposition in those areas than will distant precursor emissions? If not, can we yet reach a scientific conclusion on this fundamental issue?

   The report concluded that both observational and theoretical evidence exists for long-range transport of pollutants leading to acid deposition. Also, it is apparent that any receptor site will be influenced by both local and distant sources. A specific facility is likely to have a greater effect on a specific receptor site the closer the emitter is to that site. Sources, however, are not uniformly distributed in space. The report also concluded that currently available models of transport and transformation processes are not sufficiently accurate to determine the relative importance for deposition at specific sites of long-range transport as compared with the more direct influences of local sources. Nor are currently available data sufficient for this purpose.

4. The National Academy 1983 report contains a statement that "there is no strong evidence for a strong nonlinearity in the relationships between long-term average emissions and depositions in eastern North America." (p. 139) In English, does this mean that there is a one-to-one relationship between the amount of acid precursors emitted and the amount of acid deposition?

   The quotation in the question contains a word that does not appear in the text of the report. The sense of the quote in the question reflects the text of the report, however. The word "strong" that modifies "evidence" in the question does not appear in the text.

   The statement implies that a reduction in long-term average sulfur dioxide emissions would result in a comparable reduction in the similar average of sulfuric acid deposition. Thus, a 20 percent reduction in emissions should lead to a 20 percent reduction in deposition, a 30 percent emissions reduction to a 30 percent deposition reduction, or a 50 percent emissions reduction to a 50 percent reduction in deposition. The answer to the question then is yes, provided that the relationship is understood to be between average emissions and deposition summed over a wide region.

5. In an August 30, 1983 letter from Mr. Manowitz to Representatives Fuqua, Scheuer and Lloyd, the National Laboratory Consortium had this to say about the NAS statement:

   "A lack of evidence for nonlinearity is the empirical data by the Committee is not logically equivalent to a proof of linearity."

   Is there a conflict between the NAS scientists and the NLC scientists on this important issue?

   The relationship can be either linear or nonlinear. The NAS committee examined the data carefully, looking for evidence of nonlinearity because of the importance of this issue. The available data do not indicate that a nonlinear relationship exists. The data are not sufficient, however, to prove that a linear relationship exists. There is therefore no conflict between the report and the NLC statement. On the other hand, there are only two choices, linear and nonlinear. The data rule out the latter, so that while there is no proof of linearity, we are for practical purposes led to that conclusion. It is often easier to demonstrate a negative hypothesis, i.e., that something is not true, than a positive one, i.e., that another thing is true. That is the case in the current instance.

6. As I read the summary of the NAS report, the conclusions are mostly based on theoretical considerations and modeling exercises, rather than on a broad base of empirical data. Is this true? Is the empirical data now being collected? When will sufficient empirical data be available for the scientific community to verify their theoretical considerations and modeling exercises?

The conclusions of the report are based on analysis of empirical data (Chapter 4) and supported by evidence from laboratory experiments and by theoretical calculations. In fact, the committee began its examination of the available data with the purpose of testing them to determine the degree of nonlinearity in the relationship between emissions and deposition that had been hypothesized in a theory published in Europe in 1980. It devised several different and independent tests of empirical data for this purpose; each test produced the result described in the answer to question #5. It then undertook a review of the theory and laboratory experiments pertinent to the theory. The result of that review included correction of some errors and revision of some chemical factors that enter into the theory. After these changes, the committee obtained the results sited in the report.

Empirical data continue to be collected. More is needed of a variety of types as described in Chapter 5 of the report. A very substantial data collection effort will be required before computer models of long-range transport and chemical transformation processes can be verified. The vital needs include not only data on the chemistry of precipitation and on emissions, but also data on meteorological conditions, in-cloud processes, deposition in dry form, and transport of air parcels under different meteorological conditions.

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Department of Applied Science

Official Committee [illegible]

Richard

May 22, 1984

[illegible] RESOURCES
RECEIVED
MAY 24 1984

The Honorable James A. McClure
United States Senate
Committee on Energy
and Natural Resources
SD-361
Washington, DC 20510

Dear Senator McClure:

I am happy to respond to your letter of May 10, 1984. The questions submitted by the Committee on Energy and Natural Resources follow accompanied by the appropriate response.

Question 1. In an August 30, 1983 letter to Representatives Fugua, Scheuer and Lloyd critiquing the NAS study, you stated that "the overall feeling of the National Laboratory Consortium is that the Committee's report is flawed in several areas."

Was this your own opinion or the consensus opinion of a number of scientists at the NLC? How may NLC scientists reviewed the NAS report?

Response 1. The August 30, 1983 letter referred to was contained in my testimony to the Senate Committee on Environment and Public Works on November 2, 1983. In that same testimony I submitted cover letters from officials of the four national laboratories, copies of which are enclosed, which clearly display the consensus on the part of the four national laboratories with regard to the inadequacies of the NRC committee's report. The cover letters also identify the fifteen NLC scientists who conducted the review.

Question 2. In that letter you noted that the Chairman of the National Research Council stated in his letter transmitting the NAS study that it was the "Committee's judgment that if the emissions of sulfur dioxide from all sources in (northeastern North America) were reduced by the same fraction, the result would be a corresponding fractional reduction in deposition."

Question 2. (Cont'd) Your August 30th letter states that the "National Laboratory Consortium reviewers disagreed almost uniformly with the methods used to reach this conclusion and with the conclusion itself."

Does your August 30th statement continue to reflect accurately the opinion of the NLC reviewers on this point?

Response 2. The latest position of the NLC on this point is contained in my testimony before the House Committee on Health and the Environment on March 22, 1984. In that testimony I quote the following statement from Dr. Chris Bernabo, Executive Director of the Interagency Task Force, on the relationship between the Calvert Committee (NAS/NRC) report and the national laboratories critique:

"The criticisms of the recent NAS report expressed by the group of scientists at national laboratories appear to be more a matter of emphasis than of fundamental differences in sources of data or in interpretation.

Both the national laboratory critique and the NAS report agree that in general the detailed processes involved in acid deposition are inherently non-linear. The NAS committee expressly set out to determine the extent of the non-linearities. It found that sufficient data for the analysis were available only for assessing relationships between long-term (annual) average values of emissions and deposition integrated over large spatial scales. Several lines of evidence and theoretical calculations suggest that if non-linearities exist between annual average emissions and deposition over large areas, they are not dominant. The NAS report phrased its conclusion as 'there is no strong evidence that the relationship is non-linear' because the data are not sufficient to prove the relationship is linear. The data can only be used to assess the strength of the non-linearity.

The NAS report points out that short-term (episodes) are very complex and may indeed involve non-linearities. Non-linearities clearly arise, for example, in short-term meteorology and may be important for chemical processes taking place in clouds in winter. When the individual episodes are summed or averaged over the year, however, the non-linearities appear to balance out, or in the case of cloud processes in winter, apparently do not contribute much to annual totals.

Response 2. (Cont'd) Both the NAS report and the national laboratory scientists agree that further research on atmospheric processes is crucial to advancing our knowledge of the phenomenon of acid deposition. If we are to improve our ability to construct computer-based models useful for predicting the consequences of alternative emission control strategies, we need to study the detailed processes that occur on short temporal and spatial scales, where non-linearities can be expected. Only by building up this area of understanding can we have confidence that the models accurately reflect what is happening in nature and that reliable projection of the specific consequences of targeted emission reductions can be made.

The NAS report asserts that current models are not sufficiently tested to be relied upon for quantitative evaluations of the consequences of targeted control strategies. This conclusion is, of course, a matter of judgment. Dr. Calvert, Chairman of the NAS committee, has suggested in congressional testimony that current models can make, and have been used to make, broad-based qualitative comparisons that have provided useful contributions to the policy debate.

The seeming conflict between the NAS committee report and the comments of the National Laboratory Consortium's scientists is therefore more apparent than real, resting mainly on different approaches."

It is my understanding that Dr. Calvert and the NRC committee have reviewed that statement and concur with it. I have reviewed that statement with the NLC group and we agree that it represents an accurate and reasonable description of the situation.

Question 3. Do you believe and is it the consensus of the NLC scientists that sufficient scientific evidence is not yet available to assure that a 10 million ton reduction of sulfur dioxide emissions in the Midwestern United States will result in a 10 million ton reduction of acid deposition in the Northeastern United States?

Response 3. In responding to this question let me again quote from my testimony before the House Subcommittee on Health and the Environment on March 22, 1984:

"Let me then address what I perceive to be an interpretation by the non-technical community of the NAS committee statements. I fear that some are interpreting the term 'linearity' as that

Response 3. (Cont'd) acidic deposition will be proportional to SO_2 emissions regardless of the location of either the deposition or the emissions. This is not what the Calvert committee has said. My interpretation of the Calvert committee report statement is that if there were to be a uniform reduction of SO_2 emissions over a large area, that is, for example, the same percent reduction in SO_2 emissions for every state east of the Mississippi, then there would be a corresponding proportional-annual reduction in deposition everywhere within that large area.

On the other hand, the position of the scientific community, as I understand it, is that deposition on any given sensitive area is nowhere near proportional to emissions from any source area, but rather varies over orders of magnitude depending upon the prevailing wind direction and source receptor distance. It follows that a control strategy which is not based on source-receptor transfer considerations is highly unlikely to be as effective as one which is."

Question 4. If our objective is to reduce the occurrence of acid deposition in New England, do we have enough scientific knowledge today to design an acid precursor emission reduction program for the Midwest that will assure an equal reduction in acid deposition in New England?

Response 4. One will never achieve a reduction in deposition in New England equivalent to a reduction in emissions in the midwest. The reduction in deposition would be distributed over a variety of locations. In my judgment, present scientific knowledge does not allow a precise statement of how much deposition would be reduced in particular regions for a particular hypothetical decrease in emissions in a given region.

Question 5. Can we yet quantify the contributions to acid deposition in an area that are made by distant and near coal combustion emissions and distant and near petroleum combustion emissions, including emissions from automobiles, trucks and buses?

Response 5. In my judgment, none of these several contributions to deposition can be specified precisely at present.

Question 6. Do we understand each link in the chain of chemical events between the emission of an acid precursor and the occurrence of acid deposition in a specific region? Do we understand why acid deposition seems to occur in some areas, but not in others? Do we know the atmospheric conditions and chemical agents that must be present for acid precursor gases to result in acid deposition?

Response 6. In my judgment, the present level of understanding of the links in the chain of chemical events between emissions of acid precursors and deposition of these materials is incomplete.

Acid deposition is widespread throughout the northeast United States, albeit to differing degree in different regions. The pattern of deposition is a consequence of meteorology and chemistry as well as of the pattern of emissions. We have partial understanding of the pertinent processes (including atmospheric conditions and chemical agents) but insufficient at the present time to make precise statements about the effects of possible changes in emissions upon deposition.

The questions asked by the Committee are on priority research subjects of the National Acid Precipitation Program. They are being approached by major field observation programs. It is my belief that in several years these studies will provide basic phenomenological evidence with sufficient reliability to substantially improve control strategy options.

Sincerely,

Bernard Manowitz
Chairman

BM:mh

encs. (4)

Battelle
Pacific Northwest Laboratories
P.O. Box 999
Richland, Washington U.S.A. 99352
Telephone (509) 376-8639
Telex 15-2874

August 23, 1983

Dr. Bernard Manowitz
Chairman, Dept. of Applied Sciences
Brookhaven National Laboratory
Upton, NY 11973

Dear Bernie:

In your capacity as Chairman of the National Laboratory Consortium for Acid Deposition, you requested that we, as a NLC member Laboratory, review the National Academy of Sciences report, "Acid Deposition Atmospheric Processes in Eastern North America." Three PNL scientists, W.G.N. Slinn, M.T. Dana, and R.C. Easter, have carefully and thoroughly reviewed the report. The three were selected because of their long-standing involvement in research on precipitation scavenging processes, cloud physics and chemistry, and more specifically in recent years, the "acid rain" problem.

The findings of the three scientists regarding deficiencies of the report were uniform and unanimous. The attached summary comments represent their consolidated view.

The focus of their review was to identify the report's inadequacies and to document the unsatisfactory treatment of the nonlinearity issue. It should also be stated that the report's discussion of future research needs was good and that our scientists concur in the needs identified and the emphasis given.

Very truly yours,

C. E. Elderkin

C. E. Elderkin,
Associate Department Manager
Geosciences Research and
Engineering Department

cc: D. E. Olesen, PNL Laboratory Director
W. R. Wiley, PNL Director of Research
W. J. Bair, PNL Program Manager

OAK RIDGE NATIONAL LABORATORY
OPERATED BY
UNION CARBIDE CORPORATION
NUCLEAR DIVISION

POST OFFICE BOX X
OAK RIDGE, TENNESSEE 37830

August 29, 1983

Dr. Bernard Manowitz
Chairman, Department of
Applied Sciences
Brookhaven National Laboratory
Upton, New York 11973

Dear Dr. Manowitz:

I am writing to you in your capacity as Chairman of the National Laboratory Consortium of the Interagency Task Force on Acid Precipitation. In response to your request we have reviewed the National Academy of Sciences' report entitled "Acid Deposition: Atmospheric Processes in Eastern North America".

The attached comments were provided by a review team comprised of research scientists from several divisions within the Laboratory and from a local institution we collaborate with in several research activities. This team of scientists collectively presents considerable experience in the field of atmospheric deposition. The reviewers consisted of (A) S. E. Lindberg, a chemist with 7 years' experience and over 40 publications in the area of air pollution research with special emphasis on forest canopy/atmosphere interactions and G. M. Lovett, a biologist with 5 years' experience and 7 publications in the area of atmospheric deposition to plant canopies and chemical interactions between plants and the atmosphere; (B) F. C. Kornegay, a meteorologist with 8 years of experience and over 20 publications in the area of air quality impacts of energy production and utilization, with special emphasis on atmospheric turbulence and diffusion, and (C) B. B. Hicks, a meteorologist with over 20 years of experience and 70 publications in the areas of precipitation scavenging, dry deposition, and atmosphere/surface exchange phenomena. We believe these people are highly qualified to review the National Academy of Sciences' report.

Our reviewers express concern about inadequate discussion of uncertainty levels associated with the assumptions upon which conclusions of the NAS report are based. We believe this is an important point because of the natural tendency of nontechnical readers to develop a position or make a decision without regard to the uncertainty associated with the conclusions of a given study. You will also note an objection to the chemical, rather than a meteorological, focus of the nonlinearity issue.

Please let me know if you need additional information.

Sincerely,

Chester R. Richmond

Chester R. Richmond
Associate Director for Biomedical
and Environmental Sciences

CRR:js

Attachments

cc: S. I. Auerbach
B. B. Hicks
F. C. Kornegay
S. E. Lindberg
G. M. Lovett

BROOKHAVEN NATIONAL LABORATORY

MEMORANDUM

DATE: August 29, 1983

TO: N. Samios, Director, BNL

FROM: B. Manowitz BM

SUBJECT: Review of National Academy of Sciences Document

In my capacity of Chairman of the National Laboratory Consortium of the Interagency Task Force on Acid Precipitation, I have been asked to review the document recently issued by the National Academy of Sciences entitled "Acid Deposition - Atmospheric Processes in Eastern North America."

I have asked four scientists in my Department to review the report. They are:

Dr. Fred Lipfert (identified as Reviewer BNL-A)
Dr. Paul Michael (identified as Reviewer BNL-B)
Dr. Lawrence I. Kleinman (identified as Reviewer BNL-C)
Dr. Stephen E. Schwartz (identified as Reviewer BNL-D)

These men were selected because of their long experience and expertise in air quality research (A), meteorological and atmospheric physics research (B), air chemistry modeling (C), and atmospheric chemistry research (D).

Their comments are substantive and critical of the broad conclusions of a 1:1 proportionality between emissions and deposition implied in the Academy report.

I concur entirely with the findings of these scientists.

pt

Review ANL

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue, Argonne, Illinois 60439
Telephone 312/972-

July 26, 1983

Mr. Bernie Manowitz, Chairman
National Laboratory Consortium
Bldg. 179A, Department of Applied Science
Brookhaven National Laboratory

Dear Bernie:

The following summarizes our Atmospheric Physics Section's comments on the report entitled "Acid Deposition: Atmospheric Processes in Eastern North America", prepared by the Committee on Atmospheric Transport and Chemical Transformation for the National Research Council. Because of his broad involvement in many aspects of the National Acid Precipitation Assessment Program, most of this commentary is due to Dr. Jack Shannon, Leader of the Section's Modeling Group. Discussions have also included Dr. Marvin Wesely, Dr. In Young Lee, Dr. Romesh Kumar, and myself.

By and large, the Committee has made a useful contribution by bringing before the public--in rather the most effective fashion to date--findings of many years of research on the transport, transformation, and deposition of airborne pollutants. Nevertheless, we do have some differences of opinion relative to the Committee's conclusions, differences that are primarily matters of scale and degree. But at this stage of developing knowledge of these complex atmospheric processes, and at this point in the developing consensus for some as yet poorly defined legislative action, these differences could have far reaching consequences.

The NRC/NAS report makes a number of conclusions and recommendations which we believe are either not convincingly supported by the evidence presented, or for which we prefer alternative views supported by the evidence of our own work. These include statements such as:

1) On an annual time scale and over a 1000-km spatial scale, the formation and deposition of sulfate do not appear to be significantly nonlinear.
2) Current operational models of transport and deposition are inadequate for policy analysis.
3) Relative contributions of specific source regions to specific receptor sites are unknown.

Since each of these points deals in some way with the question of the relative "validity" of current models, it is difficult to discuss them separately. The following attempt to do so proceeds in the order presented above.

The NRC/NAS report limits its finding of "no significant nonlinearity" to the larger scales given in 1), above. Our reservations in this regard are concerned with the improved definition of these scales, specifically the determination of the shortest transport times and smallest distances below

US Department of Energy The University of Chicago Argonne Universities Association

which neglecting nonlinearity could have important consequences. Time scales over which nonlinearities may affect policy should be acconodated in the design of emission control strategies. Clearly these scales are related to ecological and material effects; effects on lakes and watersheds do seem to be largely long-term--perhaps seesonal, as in snowmelt shock. But if shorter term ecological "insults" are found to be important in current research (for example, effects on vegetation at critical stages of growth), then the magnitude of time scales for nonlinearity would need reexamination.

The 1000 km spatial scale is much larger than the distances between many combinations of source and sensitive-receptor areas. The possibility of nonlinearity over shorter distances would therefore have to be considered for the consequences of potential emission control policies to be assessed accurately. Then too, even if a uniform rollback policy were adopted, all emission sources could not be uniformly reduced because of economic or equipment constraints. Instead, rollback amounts would probably be defined over some political entity of medium scale, such as a state. Current emission levels per BTU vary widely now, and some sources are much more amenable to emission control actions than others. For instance, if a plant has already installed a scrubber, little additional emission reduction could be required of that plant if it is to continue to operate. Thus, rollback could not be expected to be uniform even when totaled by state. In short, the NRC/NAS report appears to address the issue of deposition reduction by control legislation too narrowly.

We agree with the report's conclusion that nonlinearities are more likely to occur in winter, when many transformation and removal rates are slower and transport generally faster. But even this is a qualified agreement pointing up the issue of scale: specifically, over just what distances would nonlinearity be expected to limit the efficacy of rollback legislation in these--or any--weather conditions? The consequences of the interpretation of nonlinearity are too far-reaching to be based on the limited data used.

The evidence cited by the NRC/NAS report in support of their argument for linearity is a) the ~ 15-year record of weekly bulk deposition collected at Hubbard Brook, New Hampshire, b) historical SO_2/NO_x emission estimates , and c) the observed spatial patterns of molar ratios of SO_2/NO_x emissions and sulfate/nitrate wet deposition. An apparent trend of decreasing sulfate deposition at Hubbard Brook is associated with a trend of decreasing SO_2 emission in the Northeastern U.S. But there are several difficulties with this analysis:

1. No uncertainty ranges are placed on any of the emission totals. Since the SURE, MAP3S, and MOI inventories for a single year (1978) show differences in total emissions by states of 30 to 40 percent, the historical emission data used may be equally--or even more--uncertain. Such uncertainties would swamp the apparent effects of any actual emission change.

2. Trends in Canadian emissions are not considered at all; yet the Canadian contribution to bulk deposition received in central New Hampshire, i.e., at Hubbard Brook, is probably about 25 to 40 percent of the total.

3. The apparent decrease in sulfate deposition at Hubbard Brook largely results from reference to relatively high values recorded in the initial years

(approx. 1965-1969). Since that time, there appears to have been little or no further decrease in sulfate deposition, even though emission inventories over subsequent years did continue to decrease. Meteorological variability could have accounted for this deposition record, even if there had been no change in emissions; or a single, not-too-distant source operating only in the earlier years may have gone unnoticed.

4. The decrease in the molar ratio of the sulfate/nitrate bulk deposition at Hubbard Brook also seems to result primarily from a high ratio recorded in the late 1960s followed by irregularly lower values in subsequent years. The Hubbard Brook data suggests a step function rather than a trend. The possibility of analytical error--or a change in analytical technique--could be considered.

5. The NRC/NAS report does not resolve the paradox of the apparent evidence for linearity in the Hubbard Brook data and the evidence for nonlinearity in the European data. The comparison between statewide SO_2/NO_x molar emission ratios and sulfate/nitrate wet deposition ratios used to support the linear hypothesis, is not conclusive. For example, some preliminary results of modeling sensitivity tests now underway at this Laboratory suggest that the sulfate/nitrate wet deposition molar ratio is relatively insensitive to the SO_2/NO_x emission ratio; thus a decrease in SO_x emissions may not be proportionally reflected in a subsequent decrease in sulfate wet deposition.

6. The discussion concerning whether or not the Rodhe model is adequate without a chain-carrying radical to continue the reaction, glosses over the limitation imposed by the fact that both versions of the set of equations used are essentially clear-air chemistry models, and are therefore not directly relevant to wet deposition processes.

With regard to present models, we would suggest that the relative utility of many recent assessments indicates that a number of the numerical simulations now in use have been demonstrated to be adequate for policy analysis. Future improvements in modeling now proposed (and evidently advocated for future use in assessment by the NRC/NAS report) are more likely to improve diagnostic details and field experiment design than contribute directly to improvements in policy assessment exercises. Yet the report recommends against the use of current transport and deposition models for policy assessment, thus recommending , in effect, that no cost/benefit assessment be done at this critical time of legislative decision. These negative views on present modeling capability seem to be based upon the level of parameterization necessary for tractable models, and upon the Committee's perception of the results of the now outdated MOI model intercomparison.

Taking the second point first, there were many uncertainties in the 1978 SO_x emission inventory for North America used by the MOI comparison. Further, the precipitation chemistry samples used for model verification were monthly collections and were almost entirely derived from southeastern Canada. Finally, most of the models compared had only two months of 1978 meteorological data available to them. It follows that the MOI model intercomparison was hardly a rigorous test, especially in view of the improved data sets (not to mention the improved models) available today. The NRC/NAS report does concede that some present models "quantitatively point to the importance of certain geographical groupings of SO_2 sources and the potential influence of (those) sources on certain receptor areas". It can be added that some of today's parameterized models consistently reproduce, in realistic fashion, average (monthly and longer) downstream deposition patterns attributable to large groups of sources, in the form of so-called source-receptor matrices. The "ASTRAP" model developed and used at this Laboratory, for example, achieves this degree of success with objective parameterizations of mixing, transformation, and removal processes which are based on actual measurements made in ad hoc field experiments. In other words, the model has not been arbitrarily tuned to attain this performance.

This brings us to the third point of difference. On the basis of our modeling experience, we believe that average monthly and seasonal contributions of specific source regions of significant size (say, half the area of a medium sized state) to receptor regions of similar size up to 1000-1500 km downstream, can be simulated with present models sufficiently well to make objective assessments. But until the emissions from particular source regions can be identified in deposition samples, or until large scale field experiments can be performed with realistically reacting/depositing tracers, no transport/deposition model of source/receptor relationships can be rigorously verified. Present models use real fields of meteorological data, after the fact. Indeed, it is recognized that whenever possible, assessments over a certain period (month, season) should be based on models run with several years of data in order to limit the effects of meteorological anomalies. We do not believe that there is any realistic need for a truly dynamic transport and deposition model that would operate in a meteorologically predictive mode.

Even with some uncertainties in detail, analyses of proposed emission control policies based on current models are likely to be far superior to analyses of control policies without such objective consideration of the complex source/receptor relationships. Since some emission control actions may well be taken soon, it is critically important that current knowledge of transport and deposition processes, albeit imperfectly represented in today's models, be utilized in the best interests of both the public and the industry. Recommendation against the use--and, by implication, against the continued improvement of--the parameterized models, is therefore not in the national interest, particularly since the complex, 3-dimensional Eulerian grid models promised as an alternative will not be ready to simulate even a single, specific synoptic event for 2 or 3 years. Whether these complex computerized constructs will ever be sufficiently flexible--and sufficiently economical--to operate in the multiple-scenario, quick turn-around mode required for policy assesment remains to be seen. Even then, this will not be known until 3 to 5 years, hence when the new model attains a capability of simulating a statistically significant number of events.

Sincerely,

Paul Frenzen
Associate Division Director
Environmental Research Division

PF/lac
cc: J. Rundo, Associate Laboratory Director, OTD/BER
J. Roberts, Associate Laboratory Director, OTD/EET

APPENDIX G

Statements Submitted for the Record at the Request of the Senate Committee on Energy and Natural Resources

Hearing on Acid Rain
April 30, 1984

A. Individuals

1. Dr. William M. Brown, Hudson Institute, Croton-on-Hudson, New York. Testimony taken from A Perspective on Current Acid Rain Issues, October 31, 1983.

2. James Friedman, of Guren, Merritt, Feibel, Sogg, and Cohen, Cleveland, Ohio.

3. George M. Hidy, Vice President and Chief Scientist, Environmental Research and Technology, Inc., a COMSAT Company, Westlake, California.

4. Dr. Arthur H. Johnson, Associate Professor of Soils, Department of Geology, University of Pennsylvania, Philadelphia, Pennsylvania.

5. Dr. Edward C. Krug, Assistant Soil Scientist, Department of Soil and Water, The Connecticut Agricultural Experiment Station, New Haven, Connecticut.

    a. "Acid Rain on Acid Soil: A New Perspective", by Edward C. Krug and Charles R. Frink, reprinted from Science Magazine, August 5, 1983, Volume 221, pp. 520-525.

    b. "Acid Rain: Sources and Effects in Connecticut, Report of the Acid Rain Task Force", Bulletin 809 from the Connecticut Agricultural Experiment Station, January 1983.

6. Robert E. Wayland and T. James Glauthier , Temple, Baker and Sloane, Lexington, Massachusetts.

B. Organizations

1. American Paper Institute, Washington, D.C.

   a. "Acidic Deposition and its Effects on Forest Productivity -- A Review of the Present State of Knowledge, Research Activities, and Information Needs -- Second Progress Report", Technical Bulletin No. 392, prepared by the National Council of the Paper Industry for Air and Stream Improvement, Inc. January 1983.

   b. "Report on the Development of Flue Gas Desulfurization System Capital Costs for Various-Sized Units", Special Report No. 83-06. Prepared by the National Council of the Paper Industry for Air and Stream Improvement, Inc. July 1983.

2. Council of Industrial Boiler Owners, Fairfax Station, Virginia.

   a. November 1983 CIBO Statement Before the Senate Environment Committee on S. 768, the Clean Air Act Amendments of 1983.

   b. March 1984 CIBO Statement Before the House Subcommittee on Health and the Environment on H.R. 3400, the Clean Air Act Amendments of 1984.

   c. December 20, 1983 letter to Senator Robert T. Stafford, Chairman, Committee on Environment and Public Works, supplementing testimony before the Environment and Public Works Committee, November 17, 1983.

   d. Council of Industrial Boiler Owners Issue Paper, " Guidelines for Public Acid Deposition Control Measures".

3. Electricity Consumers Resource Council, Washington, D.C.

4. Tennessee Valley Authority, Knoxville, Tennessee.

   a. Three sections of the testimony the Tennessee Valley Authority presented at a hearing of the Senate Environment and Public Works Committee, March 6, 1984.

   b. A detailed statement explaining TVA's Experience with developing an atmospheric fluidized bed boiler and plans for a demonstration facility using this technology.

   c. A TVA assessment of the status of acid deposition research.

HUDSON INSTITUTE

INTRODUCTION, EXECUTIVE SUMMARY AND OVERVIEW, AND CONCLUSIONS

William M. Brown

Taken from

A PERSPECTIVE ON CURRENT ACID RAIN ISSUES

HI-3635-RR

October 31, 1983

HUDSON INSTITUTE, INC.
Quaker Ridge Road
Croton-on-Hudson
New York 10520

A PERSPECTIVE ON CURRENT ACID RAIN ISSUES

I. INTRODUCTION

It has long been known that rain, snow, hail and other wet precipitation from the atmosphere has been acidic. Indeed, the term acid rain was coined over a hundred years ago when rain was first tested in England and found to have considerable acidity. In the less inhabited parts of the world, especially those far from industrial centers, presumably the precipitation is not polluted by anthropogenic emissions and the acidity should generally be less than one part per million (ppm). Although rainfall in a pristine environment, theoretically, would have an acidity of 0.1 ppm approximately (a pH of 5.6) that is seldom actually experienced. Indeed, rainfall with acidity greater than 1 ppm has been reported in many distant parts of the world such as remote Hawaiian Islands or even, as recently reported in the Wildlife Digest, over the tropical forests of southern Venezuela which are part of the Amazon Basin. The causes of such remarkably high rainfall acidity in such places is not yet known.

In recent years concern about acid rain--or, more technically, acid deposition--has become both a national and international issue. Claims have sprung up that various local environments or ecosystems are being damaged to a greater or lesser degree by the acidity in precipitation and some assertions even now are being made that the damage wrought might become irreversible. If these claims are substantiated by the ongoing scientific investigation then the potential environmental and ecological damage might indeed be quite significant, as also might the economic value of the various forms of damage. To date, however most of the claims about the sources and impact of acid rain are still somewhat uncertain, and in many aspects highly uncertain, if not simply wrong.

In the United States scientific calculations have shown that the contribution of anthropogenic emissions from various sources, but primarily from industrial and electric utility plants, have contributed over 90 percent of the acidity to rainfall in the eastern portions of the United States. Averaged annually the resulting concentration of acid in U.S. precipitation does not exceed 4 ppm (parts per million) in any state. Although such amounts are quite dilute, in the sense that it would not be noticeable in drinking water, for example, nevertheless 2-4 ppm is an acidity level which apears to be harmful to various forms of aquatic life. However, because most lakes and streams in this country have natural alkaline buffers the impact of the precipitation is negligible in the vast majority of lakes and streams. Whether it even has much of an impact on those waters which are poorly buffered is also in doubt, according to many investigators, as will be shown.

The extreme concern about the potential danger from acid rain has led to an increased amount of scientific research which, hopefully, will lead to definitive answers in the near future. Such research is now being carried on by scientists in several developed countries and is being principally supported by the governments of Europe and North America. In the U.S. it has become an important project for the Environmental Protection Agency (which leads an Interagency Task Force), the National Academy of Sciences, the Office of Technical Assessment. Also, major studies have been conducted by the Library of Congress, the Department of Energy and many state environmental organizations, as well as by various utilities and utility associations.

Our study has been commissioned by the Hoosiers for Economic Development Committee with the understanding that we will provide an independent perspective on the current issues and the currently proposed legislation for controlling the emissions of acid rain precursors--sulfur and nitrogen oxides, primarily. At the outset the Hoosiers Committee understood that the perspective that we would develop would depend entirely upon the evidence gathered and that the Hudson staff had no meaningful connections to any of the antagonists or protagonists that are involved in the ongoing political debates.

Our approach has been relatively straightforward. We have attempted to review the evidence about the sources, transport, and deposition of potentially acidic emissions from man-made sources through the atmosphere and back to the surface. Second, we have examined the claims about possible damage which can occur and the evidence given in support of those claims. We have also looked at arguments which contradict those assertions or find them exaggerated, or conclude that the evidence is only circumstantial and that other causes of the damage should be investigated.

We also have briefly looked at the various claims about the costs of controlling the emissions of acid precursors and tried to make a rational judgment about the reasons for the wide variations in these estimates. Also we examined the issues from various political perspectives in order to provide the reader with some background about the political process and how it might affect the outcome of the proposed acid rain legislation.

Finally the conclusions and recommendations which appear in this report are those of the authors who, in arriving at them, take a point of view that is intended to represent the national interest. That is we give relatively little consideration to the needs or goals of any special interest groups. Obviously some of our conclusions or recommendations will not be welcomed by some of these groups. Where there is disagreement we hope it will be understood that the disagreement represents an honest difference of perspectives, judgments or opinions.

II. EXECUTIVE SUMMARY AND OVERVIEW

Currently at least several hundred scientists around the world are involved in debates about various technical issues related to acid rain--at least the portion of it which stems from anthropogenic (man-made) sources. Here are some of the issues:

1. How much acid is produced? There is general agreement that the burning of hydrocarbon fuels (coal, oil, natural gas, wood, paper, in the U.S., etc.) creates emissions which contain about 25 million tons of sulfur oxides, 20 millions tons of nitrogen oxides, and smaller quantities of other less important acid precursors. A fraction of these will end up as acids in the atmosphere (primarily sulfuric and nitric acids) probably within a few days. How much of these emissions actually is converted into acids is not known, although it is undoubtedly a substantial fraction. Because the amount of acid formed depends upon many capricious meteorological factors (winds, clouds, temperature, humidity, rainfall, sunshine, turbulence) as well as atmospheric dust, time of day, season, and possibly many other non-meteorological factors (not all of which are even known) that amount is undoubtedly a highly variable quantity over time. Long-term averages, when they become determined over time by enough research, might show that roughly half of the emitted precursors eventually become acids--but that is only a guess, not a solid scientific fact. A few years of an adequately funded research program should provide a respectable answer to the question.

2. How much acid precipitation reaches the ground in the geographical areas which many people have claimed are relatively sensitive? Here again the answers are not precise, in part because of the extreme variability of the measured results. In a single rainstorm the acidity can vary greatly--by a factor of 4 or more--over the region receiving the precipitation. In fact, the measured acidity of rain at any single receptor can also vary by a similar factor during the course of a storm. It does not necessarily follow that the acidity is greater at the beginning than at the end of a storm, or the other way around. There are no simple answers to those questions.

Some of the acid formed in the atmosphere may reach the ground as "dry" precipitation. That usually means in other ways than through rain or snow and includes fogs, direct contact with surface features, and oxidation to acids of gaseous precursors after they are adsorbed onto various surfaces. Also, a portion of the acid formed is neutralized in the atmosphere or on the ground, and another portion is dissipated in the ocean.

Research efforts are now underway to provide better quantitative information about the amount of acid precipitation received in various regions of the U.S. but it will probably take a few years before high confidence can be placed in the accuracy and usefulness of the knowledge gained. Even then it is probable that knowledge about the amount of dry acid deposition will lag that of wet deposition--perhaps for a considerable time.

3. How much of the acid deposition in any particular area comes from sources which are local, how much from nearby emissions (e.g., within 200 miles), and how much comes from distant sources, several hundred miles distant or more? Currently this issue is especially important because the sources of sulfur oxide emissions that are obvious targets for regulatory control are the large coal-burning power plants which are relatively concentrated in the mid-western states while the areas claimed to be the most sensitive to acid rain are in the Adirondack Mountains of upstate New York and parts of southeastern Canada.

At the present time, even though the legislation now being proposed in Congress focuses on controlling SO_2 (sulfur dioxide) emissions from mid-western utilities, it is not known whether that program will make a significant change in the amount of acid deposition in the Adirondacks. Indeed, it would not be at all surprising to find that the program made only a barely noticeable change in the measured amount of acid rain in upstate New York even after 10 years and a commitment of $100 billion (in 1982 dollars).

On the other hand it may be possible, though not likely, that the same program could reduce the amount of acid precipitation in the Adirondacks by as much as 25 percent. However even with that favorable outcome would the effects of that change in deposition be noticeable? That is, would fish appear or be able to survive in some of the lakes which are now barren of them? Would some forests which now appear to be dying become revitalized? As we shall see, there is a very great uncertainty about achieving any observable results even under favorable assumptions about the change in the amount of acid deposition.

4. Do scientists now reasonably understand the effects of acid rain upon various parts of the environment? This may be the most important technical issue. That is, how bad is acid rain? What damage is it doing? Will it get worse over time?

A substantial part of this report will deal with those questions in some detail. We can summarize the answers that are now being given by scientists in the following way. The scientific community is strongly polarized at present. Many scientists tend to believe that acid rain is responsible for the loss of fish in some lakes and other undesirable aquatic effects in the more sensitive areas; that it poses threats to some kinds of forest in some regions; and that it has potential deleterious effects on human health as well as accelerating erosion or corrosion on exposed buildings, monuments, and vehicles. However they usually concede that the evidence is circumstantial--that is, other explanations for the observed effects, while not known, cannot be ruled out.

On the other side of the damage issue we find scientists who claim that the acidity of lakes and streams even in the most sensitive areas are due to natural causes, sometimes with an assist from past land-use practices (such as logging, fire control). In particular, they assert that the acidity of lakes and streams is almost completely determined by the soil conditions of the associated watersheds and that these conditions can hardly be affected by the small amount of acidity (2-4 parts per million) that arrives in acid rain (even at 4 ppm--equivalent to a pH of 4.1--it would take 85 years to deposit an ounce of sulfuric acid on a square foot of soil). Similar rebuttals are made to the claims that acid rain is harming the forests, or agricultural crops or that its impact on human health or on erosion or corrosion of exposed material surfaces is significant in comparison with other processes.

Indeed the only major area in which a consensus exists is that reducing emissions which create aerosols would result in improved average atmospheric visibility, but even that has not been quantified. In fact, it is at least doubtful that the improved visibility would be noticed by many citizens even after the $100 billion is spent on reducing emissions.

5. In light of the available technical information, what can be done and what should be done about acid rain now, in the near future, and over the long term? That is, what might be the best policy at the federal level?

This is a very complicated issue especially in light of the extreme uncertainties in the scientific knowledge and because of what appears to be huge costs and conjectural benefits in the currently proposed legislative initiatives. As this issue is likely to remain active for years acid-rain policy probably will be reviewed frequently as policymakers attempt to respond rationally to the political pressures and to the best technical estimates of the cost-effectiveness of various mitigative measures. Our tentative recommendation to federal policymakers is as follows:

a. Expand the national acid-precipitation research effort over the next 5 years or more, up to $150 million per year, if necessary ($18.2 million dollars were spent by the federal government in 1982). It is important to get solid scientific information if the government is to formulate reasonable responses to the potential damage from acid precipitation and to avoid costly boondoggles.

b. Encourage the development of improved cost-effective technologies for reducing the emission of acid precursors and other pollutants from all sources, large and small. These technologies are likely to be needed in many new installations in any event, and would be desirable in a program which requires extensive retrofitting. In particular, new methods of removing sulfur from coal before it becomes a flue gas appear to be potentially very valuable over the long term. The federal cost of providing incentives to private industry for such a program might exceed $200 million per year over the next several years, but if properly formulated it should be an excellent long-term investment.

c. To the extent that liming of selected lakes and streams can be shown to be a desirable and cost-effective interim, if not long term, measure for creating a desirable ecological balance that approach should be pursued. A cost-sharing federal-state prototype program might be advisable over the next ten years. It is hardly likely that even a large effort involving 200 lakes would cost as much as $20 million/year in 1983 dollars.* If it is successful it could reduce one of the major current causes of political pressure to take hasty legislative action of a costly and potentially disruptive nature.

d. An experimental retrofit program involving $.5 to $1 billion/year for controlling acid-forming emissions from major sources nearest to the sensitive Adirondack area could be the first phase of a potential long-term program of retrofitting--it remains to be proven through research that a Phase-II would be desirable. The initial retrofitting would probably involve power plants and possibly other large industries in New York, Pennsylvania, New Jersey and possibly some New England states. That experimental program could be based upon the substitution of low-sulfur coal or natural gas for present high-sulfur coal or other sulfur-containing fuels. If it were based upon the use of scrubbers it would be more costly. These changes should be integrated into the acid deposition research program in a timely manner in order to test the predicted impact of those changes against the observed results.

e. The last (and still tentative) recommendation is that due consideration be given to a stronger policy of controlling the emission of acid-forming pollutants into the atmosphere from all new fuel-burning installations and vehicles. The heart of such a program would be the requirement for some stipulated level of control technology to be incorporated into each relevant change in the nation's capital stock. That is, every new engine, boiler, furnace, heater, cooking facility, etc., purchased or installed after, say, 1984 would have to meet a specified minimum performance level. As technology progresses over time that minimum level could gradually be made more stringent. In that way as the capital stock of the nation gradually rolls over, it will become increasingly effective in reducing all air pollutants, and the acid rain precursors in particular. With such an approach a great deal of progress in reducing all air pollution should occur steadily over the long term without the ugly prospect of compulsory, unfair, costly, and possibly ineffective retrofitting.

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*According to EPRI, lake-liming costs should average about $60 per acre. The 178 Adirondack lakes in critical condition have about 7,500 acres. Thus about $4.5 million would be required for each application if all of them were to be limed. Repeat applications may be required every three years or so. EPRI, EA-2362, Feasibility Study to Utilize Liming as a Technique to Mitigate Surface Water Acidification, April 1982.

6. What could affect public opinion and the political climate in which policy decisions will be made? Public opinion attitudes indicate that the pragmatic approach to problems, particularly domestic problems, remains the same as it has been since the 1930s. On environmental issues there is a broad-based consensus which cuts across all party lines, and includes all ethnic and regional groups. Although people remain concerned about the environment, they are currently much more concerned about economic issues and they expect a balance to be struck among efforts to preserve the environment, sustain economic growth, and create more jobs. The apparent "paradox" merely means they want prosperity without too great a cost to the environment and vice versa.

Currently the general attitude of the public, although reflecting a 20-year trend of more liberal thinking on issues of personal behavior, continues to be center or center-right politically. The public's values regarding family, community, schools, etc., remain basically the same. For example, an overwhelming majority are in the center to center-right on school busing, the death penalty, and banning hand guns.

Recent polls show that environmental considerations are near the bottom of the list of most important issues, or do not even appear on the list. Inflation, unemployment, crime and the conditions of the schools are all now more important than environmental issues. On the other hand, when asked directly, citizens will express a considerable concern for the environment and would prefer that more money be spent to protect it--even if it means higher taxes, utility bills, etc. In this context it is important to understand that probably over 100 million people use the "great outdoors" for recreation.

Specifically pertinent to the question of acid deposition, an estimated 45 million fresh water fishermen, and 12 million hunters, among others, would be disturbed if they believed that it would cause serious damage to the woods, streams or lakes--or even to the aquatic flies on which the fish feed. These people love the lakes, rivers and woods and spend considerable amounts of money to preserve them. They are "professional" environmentalists in this sense. Although basically low-profile people, they can become very active if they believe their favorite recreation is threatened. However, their activism is invariably within the traditional democratic process, and they vote often in both local and national elections.

The outdoors people are different from the relatively small group of single-issue environmental activists, who have been described as "public interest elites." These elites have been found to be atypically liberal or "cosmopolitan" in their standards. Almost 60 percent have family incomes in excess of $50,000 a year and 90 percent regard themselves as liberals. Their involvement with environmental issues leads them to give economic considerations a much lower priority.

Other groups of "activist" environmentalists, however, represent a much broader following. For example, the National Clean Air Coalition includes some organizations that have long been identified with environmental issues and others which previously have not. However, its position against acid rain is relatively extreme compared to those of the American Chemical Society or the American Association for the Advancement of Science.

Potentially, a great concentration of public opinion on legislation dealing with acid rain might stem from a coalition of some otherwise unlikely partners. That could occur if the National Clean Air Coalition joined with some fishermen's groups and generated enough publicity to get other outdoors recreational groups involved.

This analysis does not imply that the larger coalition or a political groundswell is imminent. As fishermen and hunters now have higher-priority concerns, their votes are driven largely by critical economic issues. On the other hand, in tight political races their views on the acid rain issue could determine the outcome, if they become convinced of the need for action.

VII. CONCLUSIONS

1. Past data on the amount of acid precipitation--which have indicated a trend of increasing acidity--have been shown to be erroneous for several reasons. Only the data after 1978 appear to be reliable and they suggest that the average amount of acidity in precipitation has been stable.

2. The variations in the acidity of precipitation at different sites from a single storm, or during the storm at any one site can be and frequently are very large. That implies that data about the amount of acid precipitation deposited in any area can be determined only with considerable difficulty and that claims about the amounts that are being deposited in any region are not reliable.

3. The dilemma facing the Congress is that the presently-proposed acid rain control legislation will have the following characteristics:

   a. After compliance with the legislation is complete it is not certain that any change in the measured amount of acid deposition in the sensitive eastern areas will be observable.

   b. If it is observed and found to be significant (e.g., a 20 percent decline) then it is not certain that any of the desired impacts on aquatic or forest ecosystems will be observed.

   c. The only certainty is that the economic and social costs will be large.

4. Natural sources of acidity exist which could account for most of the relatively few acidified aquatic systems. The principal sources are a) the naturally acidic soil of forest floor, especially where the underlying rocks are low in alkalinity and b) wetlands (bogs or marshes) which are adjacent to lakes, or through which streams flow on the way to lakes.

5. a. Land-use effects such as clear-cut lumbering tend to reduce soil acidity. More important the remaining litter becomes susceptible to forest fires which, if they occur, will leave a strong alkaline ash that could have a beneficial impact on aquatic ecosystems for decades.

   b. Other effects such as the massive growth of the northeastern forests since the 1930s (an estimated 70 percent increase) should lead to increased soil acidity, which in turn could stress the aquatic ecosystems in areas with little alkalinity. Could the effectiveness of the U.S. Forestry Service in protecting forests have been indirectly responsible for the loss of fish in some of the sensitive areas?

6. Many additional claims of damage to human health or to materials have been suggested--usually in a somewhat scatter-gun approach and generally without substantial evidence. Although we cannot assert that those claims will be found to be without substance the available evidence that has been gathered by the EPA tends to give those claims a lower priority in their investigations. At present they do not provide sound support for control legislation.

7. Although the estimated annual costs of a 10 MTPY reduction in SO_2 ranges from $3 billion to $12 billion our estimate of these costs is from $7 to $10 billion, or roughly $100 billion in present value terms.

8. The direct economic cost of control legislation would be the highest if most utilities are constrained to comply by installing scrubbers based on current technologies. Switching to low sulfur coal is less costly in direct economic terms but would be associated with severe local unemployment in the coal states and socio-economic ripple effects that would tend to preclude that option.

9. The impact of the control legislation on any existing plans of utilities and industries to switch from oil to coal is likely to mean an abandonment of those plans and an estimated increase of oil imports by about one million barrels per day. The costs of those additional imports plus the expected higher prices that they imply for all petroleum products would increase costs to oil consumers by about $18 billion per year--roughly twice as much as the direct economic cost of operating scrubbers. People in the Northeastern part of the U.S. would be most affected by these costs. In addition, and most importantly, the prolonged U.S. dependence upon foreign oil supplies would jeopardize the nation's security.

10. There are indications of an emerging scientific backlash that is contradicting the earlier claims that acid deposition is the cause of the observed damage to aquatic and forest systems. This backlash seems to be occurring in Europe and in the U.S. and may become pronounced during the next year or so.

11. From the perspective of the national interest the use of low-sulfur coal would be preferable to the installation of scrubbers. However because of the social and political impact on the states which have large high-sulfur coal

industries it seems more likely that the preferred response to control legislation would be the use of scrubbers.

12. To prevent passage of the proposed acid rain legislation those who would be affected by it must accept the burden of proving that they are not the culprits deserving such punishment. If they are only able to prove that contention after having complied with the law, they would have no recourse--unless the Congress stipulated in advance that it would be so liable. Could such an amendment to the legislation be tolerated by the Congress?

13. a. If the arguments are convincing that reducing SO_2 emissions will stop the degradation of lakes, forests and other environments by acid rain, considerable public support for such legislation would be forthcoming. Currently, the fate of the environment is low on the public's list of "most important issues." However, preserving the environment is given a relatively high priority by the average American when a specific issue is brought to his attention. Then he is willing to be taxed or to pay higher utility bills, if he believes that the expenditures will preserve the environment. But Americans also want economic growth, jobs, and a rising standard of living without a great impact on the environment. This is typical of their pragmatic approach to most issues, and of their belief that it is possible.

    b. A large and politically powerful opposition might result from an otherwise somewhat unlikely coalition--that of environmentalist groups such as the National Clean Air Coalition together with fishermen's and other sportsmen's organizations. Given enough convincing arguments (an important assumption), millions of these sportsmen could become worried enough about game fish and animals and their habitats to actively support control legislation. This is not to say that such a coalition is likely or that it would make acid rain a high-priority issue. Fishermen and hunters, like most Americans, now have other concerns of high priority. They are seldom single-issue voters and are driven much more by critical economic issues. On the other hand, "other things being equal," if they should lean toward the views of the National Clean Air Coalition on acid rain, this issue could sway enough of their votes to make a difference in tight political races.

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April 30, 1984

Senator James A. McClure, Chairman
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Senator McClure:

I would like to thank you for the opportunity to participate in the Committee on Energy and Natural Resources' oversight of the implementation of the Acid Precipitation Act of 1980. Acid rain is one of the most politicized issues of the decade, generating far more heat than light. I believe it is important to review thoroughly the status of our evolving scientific understanding of acid rain before rushing into poorly designed and possibly unnecessary control programs. Your Committee's continuing oversight will help defuse some of the emotionalization of this issue.

My statement has been arranged to be responsive to the specific topics identified in your request for comments. I must note, at the outset, that my expertise does not lie in the field of science so that my comments on the scientific issues are only those of an informed layman. However, in an issue which is so politicized as this one, an informed layman's view is probably helpful and necessary to discern some of the broader policy implications of the acid rain debate.

THE STATE OF SCIENTIFIC KNOWLEDGE ABOUT ACID PRECIPITATION

(A) The causes and effects of acid precipitation.

New scientific information.

The most striking aspect of the current state of scientific knowledge is the number of early theories about acid rain which have been and are now disproved. It is important to identify several of these theories because they persist as myths in the political arena even though they are devoid of scientific justification.

The first of the early theories of acid rain was that the acidity (pH) of rainfall was rapidly increasing. This thesis was based upon some crude comparisons of pH sampling done several decades ago with recent sampling. We now know that the sampling techniques previously employed were so different from modern techniques as to skew the data into appearing that a rapid decrease in pH was occurring. Even environmentalist Gregory Wetstone, in his recent book Acid Rain in Europe and North America, admits that these comparisons with the early data cannot be relied upon because of flaws due to differences in the testing equipment and methodology.

Recent data collected with comparable testing equipment and procedures demonstrates that the acidity phenomenon appears to be improving, not worsening, in those areas which have been of most concern. In June, 1982, the New York Department of Environmental Conservation released data which indicated that between the periods 1975-1978 and 1980-1981, the number of lakes listed as "critical" (pH below 5.0) decreased significantly and the number of lakes listed as "satisfactory" (pH over 6.0) increased by a very large percentage. This trend has been confirmed in a series of recent reports by the U.S. Geological Survey. The USGS reports demonstrate that sulfate concentrations of surface waters in the Northeast have been improving in recent years. The fact that the early warnings of "imminent doom" were false indicates that additional study can be completed before any decision about a particular control program is made.

The second of the early theories of acid rain, which is now recognized as untrue, is that the high pH levels and expected damage from acid rain were concentrated in the northeastern United States and southeastern Canada. A cursory analysis of the prevailing wind patterns and comparatively high sulfur dioxide ("SO_2") emission levels of the Midwestern states led many to conclude that the acid rain problem was caused by the utilities and industries operating in Ohio and the Midwest. Based on this analysis, nearly all of the proposed acid rain bills target the Midwest for enormous emission cuts, while sparing the emission sources in the remainder of the country.

Our current understanding of acid rain reveals that the pH of rainfall is suspected of being "abnormally" low in regions which are not downwind of the Midwest's SO_2 emissions. A report released in April, 1984 by the National Wildlife Federation claimed that acid rain has caused damage in such disparate states as California, Minnesota, Tennessee, Virginia and Wyoming. While this report is unconfirmed and needs verification, it tends to disprove the preliminary thesis that the Midwest is responsible for all the suspected acid rain woes.

Clearly, the Midwest cannot cause acid rain in California, Minnesota or Wyoming as well as in the Adirondacks. Other agents must be responsible if the phenomenon has been accurately detected. Is it not likely that the other agent, once identified, could be responsible for the presumably low pH levels in New England? The logical principle of Ockham's Razor requires the scientist to search for consistent explanations, not case-by-case ad hoc guesswork. Whatever the ultimate explanation for these reports, there is now considerable scientific doubt about the validity of the "Midwest is the culprit" thesis.

These alternative causal agents may be found in the renewal of interest in the impact of local sources of emissions. The National Research Council (NRC) report in June, 1983 cast serious doubt on the validity of the long range transport theory. That report concluded that the only way to ensure a fifty percent (50%) reduction in acid deposition was to reduce SO_2 emissions by fifty percent (50%) from every source in "eastern North America." None of the acid rain proposals authored by the representatives from the Northeast approaches the NRC suggestion in such draconian equity.

It is useful to quote several of the NRC conclusions in full because that report has been widely misinterpreted.

> "The relative contributions of specific source regions to specific receptor sites currently remains unknown. (Summary, p. 5).
>
> The relative importance for deposition at specific sites of long range transport from distant sources as compared with the more direct influences of local sources cannot be determined from currently available data or reliably estimated using currently available models. (Summary, p. 9).
>
> It can be stated as a rule of thumb that the farther a source is from a given receptor site, the smaller its influence on that site will be per unit mass emitted. (Summary, p. 10).
>
> Because we cannot rely on current models or analysis of air-mass trajectories, we cannot objectively predict the consequences for deposition in ecologically sensitive areas of changing the spatial pattern of emissions in eastern North America, such as by reducing emissions in one area by a larger percentage than in other areas. (Summary, p. 11).
>
> Current models have not provided results that enable us to have confidence in their ability to translate SO_2 emissions from specific sources or localized groupings of sources to influences on specific sensitive receptors. (Summary, p. 6).
>
> Continuing research on acid deposition is needed to resolve or reduce the uncertainties and thereby provide information useful in making more informed public-policy decisions regarding acid deposition. (Summary, p. 2)."

Even these few samples from the NRC report demonstrate that the scientific debate over acid precipitation is far from over. The current state of knowledge about acid precipitation is inadequate to serve as a justification for any control proposals.

The importance of local sources.

Renewed interest in the impact of local sources has also resulted from the recognition that the comparison of total SO_2 emissions, by state, is misleading and irrelevant because it does not account for the vast differences in geographical size among the states.

In order to account for this difference, it is necessary to examine the emission densities of each state, that is, the amount which each state is emitting per square mile. When this data is reviewed for SO_2, the northeastern states, nearest to the alleged damage, share the top of the list.

When certain critical emissions are examined, then the importance of the emissions from the eastern states becomes more evident. The emission densities of primary sulfate are very important because primary sulfate is considered by some to be an immediate precursor of acid rain. In 1978, the top ten states in emission densities of primary sulfate were:

1. Delaware
2. Massachusetts
3. New Jersey
4. Connecticut
5. Maryland
6. Rhode Island
7. Ohio
8. New York
9. Pennsylvania
10. Indiana

Only Ohio and Indiana from the Midwest are positioned on this list and on the lower portion at that. Notice the predominance of those states closest to the alleged acid rain damage. If Quebec and Ontario were included on a combined list of total emissions of primary sulfate for 1978, they would rank second and fifth, respectively.

The relative performance in 1978 for emission densities of nitrogen oxides, another alleged precursor of acid rain, was similar:

1. New Jersey
2. Massachusetts
3. Connecticut
4. Rhode Island
5. Delaware

6. Louisiana
7. Ohio
8. Maryland
9. Pennsylvania
10. Illinois

The clear pattern which emerges from these tables is that those states and provinces which are nearest to the alleged acid rain damage have failed to control their own emissions of SO_2 and NO_X. It is apparent that the renewed emphasis on local sources of emissions is consistent with common sense.

In short, many theories about acid rain which were widely accepted at the beginning of this decade are no longer valid. Any legislation or policy built upon those outdated theories must be revised to account for the updated scientific understanding of the acid rain phenomenon.

(B) The adequacy of the Plan in advancing knowledge about acid precipitation.

It is not within the scope of my expertise to comment on the internal operation of the ten year Plan itself, but I will comment upon the political climate in which the Plan is operating. Given the political reality that a large segment of the population has been led to believe that legislative solutions to acid rain must be decided upon immediately, there exists a real possibility that the Plan may not produce results in sufficient time to be used in the development of a rational legislative solution. It would be tragic if the Plan ultimately recommended one solution, or that none was needed at all, after billions of dollars had been spent and enormous economic displacement had taken place due to the implementation of a politically contrived "solution."

I recommend that the Plan be accelerated and its funding increased, within the bounds of scientific justification, in order that the Plan might provide information useful in the political debate as quickly as possible.

I must note that the Canadian federal government has ceased funding its acid rain research projects. See "Acid Rain Studies Lapse in Canada", New York Times, April 1, 1984. It is unclear why this funding has stopped especially since every reputable study, including that by the NRC, has recommended continued study into this phenomenon if only to revise any recommended solutions.

It is also ironic that the Canadians have stopped spending funds for research, even though they continue to spend hundreds of thousands of dollars in political propaganda urging the United States to adopt an immediate control program. (I employ the term "political propaganda" in light of the recent decision by Judge Charles R. Richey of the U.S. District Court for the District of Columbia that several Canadian films on acid rain must carry the "political propaganda" label as required by the Department of Justice and the Foreign Agents Registration Act.)

(C) Whether or not there is a consensus regarding solutions to the problem.

There most assuredly is not a consensus regarding solutions to the problem. A more important point, and one now frequently overlooked, is that there is no consensus regarding the problem. The justification proffered for acid rain legislation has included considerations about human health, fish loss, tree damage, visibility, toxic metals leaching, drinking water, crop damage, damage to buildings and structures, and so on. Yet there is little or no scientific understanding of how acid rain causes many of these problems. In several cases there is scientific consensus that acid rain does not cause the alleged problem, if indeed there is a problem. We should not be so strident in our quest for solutions that we lose sight of the problem which is presumably being solved.

I believe that thorough study is the prudent way to define the problems, if any, and to resolve the acid rain debate. It is easy to score short term publicity points by committing oneself and one's country to solving an undefined problem. Yet, in the long run, such a policy only destroys credibility and breeds contempt among constituents when the actual solutions turn out to be more expensive or more difficult than originally promised. Such is the case in Canada today.

Those familiar with the general outlines of the acid rain debate are also well aware that the Canadians have been lobbying vociferously for acid rain controls in the United States for several years. The Canadians have promised to make great strides toward controlling their own SO_2 and NO_X emissions. Yet, the Canadian acid rain program is merely a shell for public relations gimmicks, with much less actual progress than already achieved by the United States under the Clean Air Act.

In November, 1981, the Canadian Parliamentary subcommittee on acid rain took a critical look of Canada's performance on acid rain and published the acclaimed report, Still Waters. This report noted that the Parliamentary subcommittee was "appalled" that Canadian NO_X emission standards for new passenger cars were three times less stringent as the American standards. The Parliamentary subcommittee recommended that the Canadian standards be tightened to the level achieved in the United States. To date, no action has been taken to tighten these standards or to reduce Canada's auto NO_X emissions and none is anticipated before the 1990 model year.

The Parliamentary subcommittee noted that Canada emits more SO_2 on a per capita basis then does the United States. Bruce Jutzi, environmental counselor at the Canadian embassy in Washington, admitted in February, 1984 that Canadian SO_2 emissions are about 99 kilograms per person compared with only 52 kilograms per person in the United States. This statistic puts to rest all of the meaningless comparisons between total SO_2 and NO_X emissions from Canada and the United States because those comparisons fail to account for the vast difference in size between the two nations and their economies. The Parliamentary subcommittee correctly began to focus the acid rain debate on the relative performance of each country on acid rain control. In such a comparison, the Canadian government fares poorly.

In all, the Still Waters report recommended 38 specific steps for the Canadian government to take in order to make its own acid rain control program equivalent to the United States' effort. In 1983, the Parliamentary subcommittee reconvened and this time its members noted that Canada's federal and provincial governments had failed to adopt the subcommittee's recommendations. I would concur with the opinion of one subcommittee member that Canada's track record on this issue is "abysmal."

Ontario Hydro's position on acid rain is a good example of the overall Canadian approach of making showy promises but failing to deliver. In 1981, Ontario Hydro proudly announced an acid rain control program designed to reduce its SO_2 emissions 43% by 1990. The centerpiece of this plan was a requirement that Ontario Hydro construct two scrubbers at its coal fired plants. A stringent NO_X emissions requirement was included. These requirements were to make Ontario Hydro a "clear leader" in this field and "one to be copied" as Hydro's press releases told the world. The Canadian government and environmentalists repeatedly used Ontario Hydro as the stick with which it battered away at American utilities on this issue.

Where does the Ontario Hydro program stand today? In February, 1982, the Province of Ontario quietly relaxed the portion of its control order dealing with NO_X controls. In July, 1982, Ontario Hydro cancelled its plans to install scrubbers on its plants despite the fact that the Parliamentary subcommittee had also recommended that the scrubbers be built. There is legitimate doubt, given the track record, whether Ontario Hydro actually will reduce its SO_2 emissions once the promised reductions become due later this decade.

Despite the recommendations of the Parliamentary subcommittee, there are no scrubbers in operation or under construction at Ontario Hydro or elsewhere in Canada. By contrast, there are over 100 scrubbers in operation in the United States and several dozens more under construction. All new coal fired plants in the United States must now include a scrubber. There is no such requirement in Canada.

Ontario Hydro's acid rain control "program" was a carefully designed public relations gimmick which drew attention away from the Province of Ontario's shoddy job of environmental control. From 1973 through 1982, Ontario Hydro's SO_2 emissions increased dramatically.

YEAR	SO_2 Emissions (tons)
1973	319,000
1974	333,000
1975	350,000
1976	413,000
1977	465,000
1978	490,000
1979	491,000
1980	445,000
1981	469,000
1982	505,000

One can measure the seriousness of this program by the fact that during the year after the reduction program was announced, Ontario Hydro's SO_2 emissions increased by 7.6%. Such a reduction program is worthy of inclusion into George Orwell's 1984 as an example of "newspeak."

As a contrast to Ontario Hydro, consider that the Cleveland Electric Illuminating Company, one of the utilities targeted by H.R. 3400 for scrubbers, reduced its SO_2 emissions by over 200,000 tons from 1973 to 1982. This translates into an enviable 36.7% reduction while Ontario Hydro was increasing its emissions by nearly 60% over the same time period. Common sense and equity demands that those who have not made reductions in the past make their first reductions before others are required to make additional sacrifices, if necessary.

Ontario Hydro's "reduction" program, like the Canadian acid rain plan in general, attempts to equate future Canadian emission reductions with future American reductions, while overlooking the fact that significant American reduction efforts are already in place. The Canadians have been very adept at comparing apples and oranges. This Committee must realize that the so-called Canadian acid rain control program has been a series of public relations moves designed merely for political consumption at home and abroad.

Even the Canadian goal of reducing its SO_2 emissions 25% by 1990 and 50% by 1994 is set in phantom terms. Canada is only promising to reduce its emissions from "allowable" 1980 levels, not actual levels. Since the 1980 actual emissions were far less than the allowable level, these reductions can be achieved by the stroke of a pen, and not by reducing the amount actually emitted. Even the Toronto Star has criticized the Canadian government for playing games with these statistics. Yet, compare the actual SO_2 emissions reductions achieved in the Midwestern states from 1976-1980.

Percent Changes in Selected State
SO_2 Emissions from 1976 to 1980

"Downwind States"	Percent	"Upwind States"	Percent
Connecticut	+27	Alabama	-23
Maine	+26	Arkansas	-31
Massachusetts	+73	Illinois	-21
New Hampshire	+60	Indiana	+7
New York	-6	Kentucky	-33
Pennsylvania	+2	Louisiana	-25
Rhode Island	+73	Michigan	-36
Vermont	+35	Mississippi	-16
		Missouri	-3
		Ohio	-21
		Tennessee	-24
		West Virginia	-7

It is more than ironic that the Canadians and the northeastern states have made their strident calls for reductions in the Midwestern emissions even as they continue to increase their own emissions. I hope that the Committee recognizes the dangers of appearing foolish like the Canadians by embarking upon an undefined program with an undefined goal before the necessary consensus and scientific understanding is achieved.

(D) The potential economic, social and environmental consequences of regulatory action in advance, or as an alternative to, implementation of the Plan.

The most important factor involved in the implementation of any regulatory action in advance of completion of the Plan is that the regulatory action would be based upon inadequate information. While all regulatory action occurs, to some extent, in the absence of perfect knowledge, rarely have there been proposals which would assuredly cost billions of dollars, thousands of jobs and economic dislocations with so little assurance of benefit as many of the current acid rain control plans.

My discussion of the economic impacts of the various regulatory proposals is contained later. Suffice it to say that the impact of the proposals is such that they may profoundly disrupt the competitive balance of the various regions and tip that balance decidely against the Midwest. This constitutes the certain cost of regulatory action in advance of the Plan.

The benefits of such action are slim and uncertain. There is no scientific consensus on whether a particular control plan will be effective in reducing deposition in sufficient amount in the targeted areas. There is no consensus that a

SO_2 control plan is needed at all. Even assuming that a reduction in SO_2 emissions is desirable, then that reduction will be achieved under the current Clean Air Act without additional regulatory action.

Under the current Clean Air Act, SO_2 emissions in the Midwest have been decreasing and will continue to decrease. One recent study estimates that the Midwest's SO_2 emissions will decline by 16% from current levels by the year 1990 without acid rain legislation. These reductions will be achieved by the retirement of some existing coal-fired capacity and its replacement with units covered by the stringent new source performance standards.

After 1990, it is estimated that the Midwest's SO_2 emissions will continue to decrease without additional regulatory action. The expected development of new generating technologies such as coal gasification, LIMB and fluidized bed will allow coal to be burned cleaner than by using the scrubbers which H.R. 3400 would impose. It was estimated in the November, 1983 EPRI Journal that employment of these new technologies will reduce total SO_2 emissions to under 5 million tons per year shortly after the year 2000. However, if scrubbers must be built on existing plants, the development of these new technologies will be inhibited and total SO_2 emissions after the year 2000 will stabilize closer to 10 million tons per year. It is a simple fact that if utilities are required to spend billions to install scrubber equipment, they will not decommission that equipment 5 or 10 years later and spend additional millions or billions on installation of any of the new generating technologies. The crucial fact to remember is that emissions will be significantly reduced without additional regulatory action.

These estimates do not account for the numerous SO_2 emission increases made by the northeastern states in the last few years by obtaining variances from the current Clean Air Act requirements. A listing of these emission increases have been made each year by the Environmental Protection Agency and given to Senator Mitchell of Maine as the so-called "Mitchell Reports." A new set of variances sought and received by the New England states was published in the March 15, 1984 Federal Register. These emission increases are important because they are so close to the allegedly sensitive areas that their impact is much greater than the emissions of sources hundreds of miles away.

ANALYSIS OF LEGISLATIVE AND REGULATORY PROPOSALS

My comments in this area will focus on several items. First, the cost of electricity and other impacts upon Ohio of several of the legislative and regulatory proposals. Second, the shortcomings of the proposed legislation. Third, the manner in which those proposals would alter the existing pattern of fuel use, most notably, by increasing the amount of electricity imported into this country from Canada.

(A) The Impact Upon Ohio.

Nearly all of the current proposals for legislative or regulatory action target Ohio for SO_2 emission reductions in the range of 60-70% despite the fact that Ohio reduced its SO_2 emissions by 21% from 1976 to 1980. Few other states, and certainly none of the northeastern states, are asked to bear such a large burden. Despite the variety of allocation formulas which have been proposed, the end result is that Ohio is forced to reduce its SO_2 emissions by 60-70% whether the proposal is S.768, H.R. 3400, H.R. 5314, the National Governors Association proposal, or the Ruckelshaus so-called "Option III."

In May, 1983, the Congressional Research Service estimated that an 8 million ton SO_2 reduction would result in an approximately 50% reduction in the production of Ohio coal. This production loss would cost Ohio roughly 19,000 to 21,000 jobs as a result of the lost mining. The United Mine Workers has estimated that such a bill could cost 80,000 mining related jobs nationwide.

A more likely scenario would include the prohibition of fuel switching through mandatory scrubber requirements as in H.R. 3400 or under Section 125 of the Clean Air Act. This would attempt to protect the miners' jobs by forcing the costs of compliance onto the electric utilities and their customers. This scenario has been estimated by the State of Ohio's Office of Consumer Counsel to raise statewide average residential rates by 12.8% to 18.2%.

The Cleveland Electric Illuminating Company ("CEI") has estimated that H.R. 3400 would require an average increase in rates of 13%-21% from 1991 to 1996. This would occur even though CEI's residential rates are already the 12th highest in the nation (750 kwh/month). Such a rate increase would have a devastating economic impact upon northeastern Ohio, further eroding the area's ability to compete in the national and international marketplace.

I place particular emphasis upon the CEI rate ranking because it belies the charge from the Northeast that the Midwest can afford the costs of acid rain controls because the Midwest has cheaper electricity rates than does the Northeast. In fact, CEI's rates are higher than the rates in all of Connecticut, all of Maine, all of Massachusetts (including Boston) except Nantucket, all of New Hampshire, all of Rhode Island, and all of Vermont. With respect to Northeast Ohio, the "cheap electricity rates" argument is plainly false.

(B) The Shortcomings of the Proposed Legislation.

Many of the legislative or regulatory proposals use 1980 as a base year. While this is a seemingly noncontroversial point, it actually discriminates against the Midwest. What is the scientific basis for selection of 1980 as base year? Was 1980 the year when the spatial pattern of SO_2 emissions caused the most acid rain damage?

Arbitrary selection of 1980 discriminates directly against the Midwest because it fails to grant the midwestern states credit for the significant SO_2 emission decreases achieved from 1976 to 1980. The selection of 1980 appears to be more than coincidence when you recall the dramatic emission increases which occurred and continue to occur in the northeastern states since 1976. The selection of 1980 as base year would "grandfather in" those northeastern emissions increases. Indeed, the minimal SO_2 reductions which most proposals would impose upon the northeastern states would not even rollback the emissions in many of those states to the levels emitted in 1976. Even the Ohio Environmental Council has expressed reservation about the fairness of using 1980 as a base year. Far from being a noncontroversial point, use of a 1980 base year demonstrates a distinctly anti-midwestern bias.

Several bills, notably H.R. 3400, provide for some sort of cost sharing mechanism purportedly designed to help the Midwest bear some of this enormous cost. In the case of H.R. 3400, the fund would leave far too many costs to be absorbed by the ratepayers in the Midwest. H.R. 3400 promises to repay only 90% of the capital costs incurred to construct the scrubbers. Since there is no scientific evidence identifying the Midwest as the cause of the acidification of northeastern lakes, then costs of a politically-motivated emissions reduction bill such as H.R. 3400 should be shared equally. H.R. 3400 does not even attempt to subsidize operating and maintenance costs which become an increasingly larger component of costs as the scrubber ages.

There is a more fundamental problem with the funding mechanism of H.R. 3400. While this bill promises to finance 90% of the capital costs for construction of the scrubbers it requries, every study of which I am aware demonstrates that the 1 mill tax per kwh is insufficient to cover even 90% of the capital costs.

The September 1983 study by Temple, Barker & Sloane (TBS) revealed that the 1 mill tax would only cover 80%, not 90%, of the compliance capital costs. A 4.3 mill tax would be necessary to cover all compliance costs of H.R. 3400, including operating and maintenance costs and fuel costs. The TBS study also revealed that the fund as presently proposed does a poor job of subsidizing costs. Even with the subsidies from the fund, compliance costs per household would be reduced by only 25% in those states hardest hit.

In September 1983 the Congressional Research Service (CRS), with assistance from the Office of Technology Assessment, concluded that because of the proposed start-up date of the fee and the 1990 compliance date, the H.R. 3400 fund, under nearly all the scenarios examined by CRS, accrued insufficient revenues to pay off its outstanding obligations at the end of each year. It should be clear to all that the promised 90% reimbursement figure is inaccurate. The 1 mill tax does little to share the costs of this bill.

Another shortcoming of H.R. 3400 is the mandatory obligation to install scrubbers on the top 50 SO_2 emitting plants in 1980. It is more than a coincidence that not one of these targeted plants is located in New York or New England. Nearly 60% of these plants are located in only 5 states: Ohio (9), Indiana (7), Illinois (4), Kentucky (4) and West Virginia (4).

Most of these plants are unable to retrofit scrubbers due to age, size or space constraints. The TBS study noted that although there are 195 generating units at these 50 plants, only 41% of these units are candidates for scrubbing (based on units of 200 MW or greater built since 1960). If fuel switching is required at the remaining 59% of these units, then the spectre of miner unemployment raises up again. It is important to consider these limitations. Indeed, the September 1983 CRS study noted earlier recognized that "the question of installing expensive FGD equipment at the older and smaller of the facilities must be raised." (Page 26).

A study completed in April 1983 by PEDCo. Environmental for the U.S. Department of Energy ("Acid Rain Boiler Population Retrofit Analysis") identified four factors that would preclude retrofit of scrubbers:

1. The boiler is too small. It is uneconomical to retrofit FGD onto a boiler smaller than 100 MW.

2. The boiler is too old. Any boiler built before 1950 would not have enough remaining life to make FGD retrofit practical.

3. Space constraints make retrofit too expensive.

4. There is physically not enough room at the site to retrofit, regardless of cost.

Despite the wealth of information and studies concerning the impracticality of retrofitting FGD onto certain untis, H.R. 3400 would specifically require retrofitting at 50 arbitrarily selected plants. It appears that the draftsmen of H.R. 3400 deliberately set out to construct the most expensive and impractical proposal possible. It is apparent that politics, not science, economics or logic, is the driving force behind H.R. 3400.

There is yet another problem inherent in the structure of H.R. 3400 which has received inadequate attention. How will the problem of sludge disposal be handled? The amount of sludge which will be generated by scrubbers on the SO_2 targeted plants will be enormous. Given the huge amounts of water and limestone employed in a scrubber, 7-8 tons of sludge will be generated for every ton of SO_2 emissions reduced.

These considerations apply directly to H.R. 3400. If scrubbers may be required in several states under Section 125, then these considerations must apply to the proposals such as S.768 which do not mandate technology at the federal level.

It is clear that the acid rain proposals currently debated are fundamentally flawed. There is not even a consensus on the basic underlying facts from which a control program can be designed, if needed. It is necessary that the Plan commenced by the Acid Precipitation Act of 1980 be completed and that all of these factors, among others be considered before a control program is adopted.

(C) Changing Patterns of Fuel Use -- Canadian Electricity Imports.

It is impossible to achieve any permanent accomodation of the competing interests symbolized by the acid rain controversy without recognizing the broad economic, energy and political context within which the parties to the dispute are operating. I have commented upon some of the economic and energy realities facing Ohio today and I have attempted to show how the ill-conceived acid rain proposals currently under consideration threaten the economic livelihood of the Midwest.

Another aspect of the dispute which has not been examined in sufficient detail is the manner in which acid rain legislation will enhance Canadian electricity exports to the United States.

By 1981, Canada's growing exports of electricity had reached a level of $793 million dollars (Canadian). Those exports have continued to expand rapidly and reached $1.2 billion (Canadian) for 1983 despite the recession. There are clear and unmistakable signs that the Canadians want and need these exports to continue to grow significantly. Electricity exports have received the support of the federal government's Minister of Energy and the various provincial governments. The government-owned electric utilities, particularly Ontario Hydro and Quebec Hydro, have been aggressively seeking new markets in the United States for their power.

Canada's campaign to export additional electricty was documented in a paper, entitled The Silent Alliance, which I prepared in 1983. Senator Ford of Kentucky kindly arranged for an early version of this paper to be reprinted in the Congressional Record on October 31, 1983. The updated version of this paper will soon be published in book form by the Regnery Gateway publishing house. If you or other Committee members have not had an opportunity to review this detailed article, I have attached a copy of the Congressional Record reprint to the end of my prepared statement. I will also send a copy of my book to you when it is published.

Briefly, there are three reasons why Canada must expand its electricity exports to the United States. First, the exports are profitable. The reported dollar value of exports is already over $1 billion annually and growing rapidly. There are estimates that such sales could quadruple or quintuple under the right circumstances. The Canadians foresee the most lucrative markets in the United States as running down both coasts and they have concentrated most of their marketing efforts in those regions.

An additional export market for Canadian electricity could be the American Midwest, where the coal-fired capacity has proven to be an obstacle to Canada's electricity export plans in more ways than one. Until now, this coal-fired capacity has enabled the midwestern utilities to meet the Canadians' pricing policies on their own terms. In addition, the midwestern utilities have also competed effectively with Canada's attempts to export electricity to America's east coast. You are probably aware that the proposed export deal between Ontario Hydro and General Public Utilities (GPU) was cancelled in 1982 when GPU found a less expensive and more stable domestic source of power in Detroit Edison. Clearly, the enactment of acid rain controls directed mainly at the coal-fired capacity in the American Midwest would remove both an obstacle and a competitor to Canada's electricity export plans.

The second reason why Canada must continue to export electricity is because of the enormous number of jobs it creates. The multibillion dollar James Bay hydro project in Quebec has created thousands of construction jobs. Yet, as the New York Times reported on January 29, 1984, unless Quebec Hydro can locate additional purchasers for the power generated at James Bay, the continuing construction projects must halt with a devastating impact upon Quebec Hydro and Quebec's economy.

Similarly, the Canadian nuclear power industry has saturated Canada's demand for nuclear reactors. The Canadians have attempted to sell reactors to other countries and have proposed building reactors whose output would be dedicated to export to the United States. Canada's desperation for new reactor sales stems from the fact that without such sales, the Canadian nuclear industry will be disbanded and over 35,000 skilled workers unemployed. To compound the situation, the Canadians will lose the expertise necessary to construct new reactors in the future when the Canadian demand for electricity grows sufficiently.

James Jay, Jr., President of the Utility Workers Union of America, has estimated that the 3.5 billion kwh of electricity exported each year to the United States by Canada is equivalent to the entire production of 26 United States plants. He estimates that, due to these imports, approximately 13,000 full time American jobs have been transferred to Canada. In addition, over 150,000 construction workers have been denied the years of work required to build this new capacity. Since acid rain controls will lead to increased electricity exports from Canada, we must also be aware of the additional thousands of American jobs which will be lost to Canada. These are not only the miners' jobs which some acid rain bills would try to protect, but jobs of the Americans who would have worked to generate the electricity imported from Canada.

The third reason why Canada needs to export electricity to the United States is to gain the American revenue and capital needed to develop Canada's electricity resources. There have been numerous proposals from Canada to construct nuclear or hydro plants dedicated to long term export to the United States. However, the Canadians have made it quite clear that when Canadian demand grows to levels where these facilities are needed to supply Canadians, the transmission lines to United States will be turned off.

There should be extensive public discussion of how the United States intends to deal with the national security aspects of increased dependence upon a foreign source of energy which would result directly from acid rain legislation. Already, the Canadian electricity exports would more than supply the approximately 4.5 million residential customers in the six New England states. The ever increasing amounts of Canadian electricity exports to the United States pose the clear and present danger of dollars and jobs flowing out of this country to Canada and of an ever increasing reliance upon a foreign source of energy. You may recall that the great Northeast blackout of 1965 started with a mechanical breakdown at Ontario Hydro.

The broader context of the acid rain issue extends into the realm of national security by virtue of the increasing reliance upon the foreign source of energy. Any acid rain legislation deserves the same degree of scrutiny accorded to such issues. Since the enactment of acid rain legislation, particularly legislation directed at the utilities in the Midwest, would redound to Canada's competitive advantage, we must carefully weigh the long term, national security and strategic disadvantages which would result from this legislation.

The growing exports of Canadian electricity even now impact upon the manner in which the acid rain debate is evolving in this country. The great majority of these exports are now made to the New England states and to New York, which are precisely those states which have entered into the political alliances on acid rain with the Canadian provinces. The economic links and dependence forged by these exports make it even less likely that these states and provinces will take a position inimical to the general goal of placing the midwestern coal-fired utilities at an economic disadvantage by requiring them to make costly reductions of SO_2 emissions.

SUMMARY

I trust that my statement assists you and the Committee with your continuing oversight duties. Acid rain is a potentially serious problem which deserves detailed and thorough study. The Acid Precipitation Act of 1980 created the framework for the coordination of that study. Enactment of acid rain legislation at this time, based upon the inadequate scientific understanding of the phenomenon would make meaningless the valuable work done to date and planned for the future under the Act.

In 1980, Congress set this nation on a prudent course for dealing with acid rain. Alterations of that course at this early juncture would be injudicious, at best, and potentially hazardous to the economic health of the nation.

Very truly yours,

James M. Friedman

if the Senator has no more need for time we can start morning business early then.

Mr. BYRD. Very well.

Mr. BAKER. All right.

Mr. BYRD. So the majority leader wishes me to do it now?

Mr. BAKER. Yes.

Mr. BYRD. I thank the majority leader.

NATIONAL SCHOOL LUNCH ACT AND THE CHILD NUTRITION ACT OF 1966 AMENDMENTS

Mr. BYRD. Mr. President, I ask for the second reading of H.R. 4091.

The PRESIDING OFFICER. The bill will be read the second time.

The assistant legislative clerk read as follows.

A bill (H.R. 4091) to amend the National School Lunch Act and the Child Nutrition Act of 1966 to improve the operation of programs authorized under such Acts, and for other purposes.

Mr. BAKER. Mr. President, I object to further consideration of the bill at this time.

The PRESIDING OFFICER. Objection is heard.

Objection to further consideration having been heard after second reading, the bill will be placed on the calendar.

ROUTINE MORNING BUSINESS

The PRESIDING OFFICER. Under the previous order there will now be a period for the transaction of routine morning business for not to exceed 1 hour with statements therein limited to 10 minutes each.

THE REAL REASON

Mr. FORD. Mr. President, I am on record as being highly suspicious of the motives behind Canada's big push for the adoption of acid rain control legislation in the United States. In a floor statement given last September, I pointed out that,

> * * * While castigating the United States for doing nothing and lobbying us heavily for the passage of legislation, Canada's approach to the very same problem has been to do little more than talk.

Indeed, Canada has nothing comparable to the stringent restrictions on sulfur emissions that we have under the Clean Air Act. Furthermore, Canada does not have a single operating scrubber on a utility plant. The United States on the other hand, has almost 100 operating scrubbers in place with dozens more under construction.

I continued my speech saying,

> H. L. Mencken used to hold that there are two reasons for doing everything: "there's the good reason, then there's the real reason." I find Canada's chagrin with the United States interesting in light of its own inaction, but it is even more fascinating when one considers the very real possibility that the export of Canadian power stands to make a quantum jump with the passage of an American acid rain plan.

Well, Mr. President, the very real possibility of a huge increase in power exports is rapidly becoming fact, and my suspicions of the real reason for Canada's intense lobbying efforts are rapidly becoming confirmed. Consider this one telling example, a forecast of things to come: on August 12, Vermont Electric Transmission Co., signed an agreement to build a line to Hydro Quebec Interconnection for a projected 2,000 megawatts of Canadian hydro and nuclear power.

The linkage between Canada's acid rain publicity campaign and additional Canadian electricity exports has been well documented in a study by James S. Friedman and Michael S. McMahon entitled, "The Silent Alliance: Canada's Efforts to Enact Acid Rain Controls in the United States and Gain Additional Electricity Exports." In their introduction, the authors quickly come to the real reason behind Canada's advocacy of control legislation: "The Canadian lobbying effort for electricity exports is rooted in Canada's need for the profits and increased employment from exploitation of its rich energy resources." But, perhaps even more chilling to some of my colleagues, is the declaration that "(W)ithout increased sales to the United States, the Canadian nuclear power industry will probably be dismantled * * *"

Mr. President, I ask unanimous consent to have printed in the RECORD a report by James M. Friedman and Michael S. McMahon.

There being no objection, the report was ordered to be printed in the RECORD, as follows:

THE SILENT ALLIANCE: CANADA'S EFFORTS TO ENACT ACID RAIN CONTROLS IN THE UNITED STATES AND GAIN ADDITIONAL ELECTRICITY EXPORTS

(By James M. Friedman and Michael S. McMahon)

For several years, Canadian officials have conducted an aggressive and highly visible lobbying effort aimed at the imposition of acid rain controls in the United States. During that same period, Canadians have mounted an equally aggressive, though not as visible, marketing effort designed to increase Canadian electricity exports to the United States. Although these same officials have denied that any connection exists between the two programs, the imposition of drastic acid rain controls on United States power plants, as requested by Canadian officials, would redound to Canada's competitive advantage. Recent studies and developments demonstrate just how close is the connection between the two issues.

The Canadian lobbying effort for electricity exports is rooted in Canada's need for the profits and increased employment from exploitation of its rich energy resources. Without increased sales to the United Sates, the Canadian nuclear power industry will probably be dismantled and then unable to meet the Canadian electricity demand which is expected to grow at the end of this century. Additional electricity exports also allow Canada to use American financing to develop generation facilities which may be turned to Canadian use once Canadian demand grows sufficiently.

These developments raise special national concerns which American lawmakers should carefully consider prior to the enactment of acid rain legislation. First, large scale importation of Canadian electricity would mean that employment and income would be created for Canadian workers and lost to American workers. The Canadians have proposed construction of generating facilities dedicated solely for export to the United States even though there may be excess generating capacity in the United States.

Second, the United States would be increasing its dependence upon another foreign source of energy just as it has begun reducing its reliance upon foreign oil. The Canadians have discussed terminating electricity exports to the United States in the future in order to satisfy future Canadian energy demand, demonstrating that Canada is not a dependable long-term supplier of electricity.

Third, the United States may be economically coerced into financing Canadian nuclear power plant expansion and disposing of Canadian nuclear waste in order to maintain an adequate supply of electricity. These and other developments should be carefully weighed by Congress before submitting to the dual Canadian lobbying efforts.

I. INTRODUCTION

For several years, Canadian officials have conducted an aggressive and highly visible lobbying effort aimed at the imposition of acid rain controls in the United States. During that same period, Canadians have conducted an equally aggressive, though not as visible, marketing effort designed to increase Canadian electricity exports to the United States. Although these same officials have denied that any connection exists between the two programs, the imposition of drastic acid rain controls on United States power plants, as requested by Canadian officials, would redound to Canada's competitive advantage.[1]

Several new studies and developments demonstrate that the Canadian export marketing effort is more serious and has deeper roots than previously identified. The recent urgency on the part of the Canadians to expand electricity exports coincides with Canada's increased efforts on the issue of acid rain.

These studies and developments also demonstrate that the enactment of acid rain controls will significantly enhance the demand for Canadian electricity. The implications of increased dependence upon Canadian electricity should be carefully examined before enacting legislation which may have irreversible economic effects.

II. CANADA AND ELECTRICITY EXPORTS

A. *The significance of Canada's electricity exports*

The United States and Canada have been exchanging electricity since 1901 when a transmission line was constructed at Niagara Falls. Not long ago, the total amount of electricity exchanged between the two countries was still small. As recently as 1968, the United States exported more electricity to Canada than it imported.[2]

During the late 1970's, however, the electricity exchanges began to grow dramatically and increasingly favored Canada.

Footnotes at end of article.

TABLE I—TRADE IN ELECTRIC POWER[a]

[illegible]

Year	U.S. exports	Canada exports	Net U.S. imports
[illegible]	[illegible]	12 804	9 214
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	31,371

[a] [illegible]

As seen on Table I, exports of Canadian electricity increased between 1976 and 1982 from 12,804 gigawatthours ("GWh") to over 34,000 GWh, an increase of 267 percent. To examine the imbalance of this trade, consider that net United States electricity imports increased 340 percent, from 9,214 GWh to 31,371 GWh.

Not unexpectedly, the dollar value of these electricity exchanges increased dramatically over the same period.

TABLE II.—*Gross dollar value of Canadian exports of electricity*[a]

[In million Canadian dollars]

1975	104.9
1976	173.8
1977	419.3
1978	478.6
1979	738.5
1980	793.6
1981	1,143.9
1982	1,105.9

[a] Ministry of Energy, Mines and Resources, Canada "Electric Power in Canada," Energy Policy Sector 1979, p. 26 (data for 1975-77); Canadian National Energy Board 1982 Annual Report, p. 60 (data for years 1978-82).

In the eight years from 1975 until 1982, the gross dollar value of Canadian exports of electricity rose ten-fold to over $1 billion dollars annually. A recent report prepared for the Canadian Electrical Association projects that Canada's electricity export revenues could rise to over $4 billion by the year 2000.[6] Clearly, these exports constitute a significant amount of electricity and revenue.

Another test of the significance of these exports is to view them as a percentage of generation and projected demand. It has been estimated that Hydro Quebec has enough surplus capacity to provide up to 95 percent of New York State's new demand through the year 2000.[8] The electricity which Canada exported to the United States in 1981 would more than supply the annual electric needs of the approximately 4.5 million residential customers of the six New England states.[7]

Electricity exports constitute an increasingly large part of total Canadian generation. In 1978, net exports of electricity represented 6 percent of net Canadian electricity generation. By 1981, it represented 9 percent.[8]

Additional electricity exports are planned. The Power Authority of the State of New York plans to increase its annual imports from Quebec by 4,300 GWh and from Ontario by 3,200 GWh. The New England Power Pool could be importing up to 16,600 GWh when a proposed interconnection is expanded in 1990.[9] British Columbia Hydro recently signed a contract to sell power to the City of Seattle for $21.8 million annually.[10] The fact that the Canadian government is considering construrtion of generation facilities solely for export is indication of the importance which the Canadians place on these exports.[11]

The growth of Canada's electricity exports, particularly in terms of size and dollar value, indicates that these exports are a trade commodity which should be monitored even if acid rain controls were not involved. The potential for huge increases in these exports as a result of American acid rain controls should be a matter of national attention.

B. Canada's lobbying for additional electricity exports

The steps which Canada has taken to build an internal consensus for additional electricity exports and then to aggressively seek such exports have been unmistakable.

In February, 1980, the Royal Commission on Electric Power Planning released its five year report on the long range planning concepts of Ontario Hydro. The Commission noted the "potential for profitable export sales, especially sales to the United States" and stated that the "advantages of interconnections between Ontario and Michigan, and Ontario and New York cannot be overemphasized."[12] In October 1981, Arthur Porter, former chairman of the Royal Commission, publicly urged the Province of Ontario to construct a nuclear power station dedicated for export to the United States.[13]

In 1981, Robert Bourassa, the former Premier of Quebec, extolled the benefits of increased hydro power exports to the United States.[14] Bourassa suggested that the then $20 billion James Bay hydro project could be financed with American capital.[15]

The December 1982, report by the Canadian Energy Research Institute investigated potential benefits and costs of increased electricity exports to the United States and recommended that "a more vigorous export policy would be in the national economic interest." The report also recommended that the Canadian government undertake an extensive information campaign to convince United States utilities to purchase Canadian electricity.[16]

The then Canadian Minister of Energy, Marc Lalonde, travelled to the United States National Governors Conference in Afton, Oklahoma to advertise Canada's willingness to enter into long-term contracts up to 25 years, even though most previous contracts had tended to be short- or medium-term. Lalonde also expressed the willingness on the part of the Government of Canada to construct a nuclear generating station with most of its production destined for the United States.[17]

Lalonde made speeches across the United States in 1982 to promote Canadian electricity. At the New England Conference of Public Utility Commissioners in Rockport, Maine on June 23, 1982, Lalonde encouraged the commissioners to approve additional imports and prevent regulatory delays.[18]

When Jean Chretien succeeded Lalonde as Minister of Energy in 1983, he continued Lalonde's strong support for electricity exports and long-term dedicated exports of electricity, in particular.[19]

In November, 1981, Ontario Energy Minister Robert Welch flew to San Francisco to promote Canadian nuclear power at the Atomic Industrial Forum meeting.[20] Also in 1981, Canada's Federal Ministry of Energy, Mines and Resources sent two officials on a tour of the eastern United States to find a market for Canadian nuclear electricity.[21]

Several proposals to sell Canadian electricity deep into the United States, away from the border areas, have received serious consideration. For example, The MANDAN project, which consists of a 500 KV transmission line running from Manitoba through North Dakota and South Dakota to Nebraska, has been under development for years.[22] These proposals do not seem farfetched in light of British Columbia Hydro's current electricity exports to San Diego Gas & Electric.[23]

Ontario Hydro officials have apparently joined the campaign for increased exports. In September 1981, Milan Nastich, President of Ontario Hydro spoke before the American Public Power Association. Nastich stated that there were no technical or financial obstacles to multi billion dollar exports and only the "political will" was needed to resolve the issue.[24] A year later, Hugh Macaulay, Chairman of Ontario Hydro delivered a speech weighing the benefits of additional exports.[25] Ontario Hydro has even taken a quarter-page advertisement in the Wall Street Journal to promote additional power sales to the United States, further demonstrating Ontario Hydro's participation in the campaign to increase electricity exports.[26]

Quebec Hydro officials have also actively promoted increased electrical exports into the United States. Premier Rene Levesque and several Quebec ministers attended the Conference of New England Governors and Easter Canadian Premiers in Rockport, Maine in June 1982, to boost energy sales to the United States.[27] At the June 1983 conference of premiers and governors in Charlottetown on Prince Edward Island, Canada, the Canadian premiers made a "massive energy sales pitch."[28] In October 1982, Quebec Hydro inaugurated a new control center to manage the generation and transmission of all Quebec Hydro's electric power. This new system better enables Quebec Hydro to judge the amount of surplus power available for export.[29]

The Quebec Hydro Development Plan for 1983-85, released in October 1982, places special emphasis on the promotion of exports. The plan recommends "intensified marketing" by Quebec Hydro including daily monitoring of market trends of neighboring American utilities to "identify sales possibilities and determine the situation of Quebec Hydro's competitors."[30]

The evidence of Canada's intentions and plans to export additional electricity to the United States is unmistakable. The seriousness of Canada's moves on electricity imports can be demonstrated by analyzing Canada's incentives and needs to export additional electricity.

C. Canada's needs and incentives to make additional electricity exports

Canada has at least three important incentives to export additional electricity to the United States.[31] First, electricity exports are profitable, especially under the Canadian method of pricing. Second, expansion of generating capacity would employ many Canadian workers. Third, Canada can utilize American financial assistance in the development of additional generating capacity.

1. Profitability of Electricity Exports

The profitability of electricity exports is sufficient incentive for Canada to take steps to increase those exports. In 1982, the reported dollar value of Canadian electricity exports totalled over $1.1 billion.[32] The recent study by the Canadian Energy Research Institute projected net revenues from Canadian electricity exports and the economic impact in terms of Canadian income and employment. Some of these results are displayed on Appendix 1. That study concluded that the total regional impact of increased power exports exceeds the impact of most other commodities.[33]

In a speech to the Canadian Nuclear Association on June 14, 1983, R.F. Brooks, Vice-Chairman of the Canadian National Energy Board, revealed that the National Energy

Board had estimated that Canadian utilities receive profits up to 39 mills per kWh on surplus hydro energy costing only a few mills per kWh. The National Energy Board also estimated that there have been profits of over 20 mills per kWh on exports of surplus coal produced energy.

As further evidence to establish the importance of electricity export profits to Canada, consider:

(a) Ontario Hydro received governmental approval of its proposed sale to General Public Utilities ("GPU") after claiming that the Ontario economy would lose $3.5 billion if the sale was prohibited. The sale was approved by the Canadian National Energy Board but ultimately cancelled by GPU.

(b) Quebec currently purchases power from Newfoundland under a long term contract and resells the Newfoundland power to the United States at a significant profit. Quebec Premier Rene Levesque has threatened to sabotage any trans-Quebec power lines built to carry Newfoundland power directly to the United States markets. In return, Newfoundland has promised to challenge Quebec's electricity exports at the Canadian National Energy Board.

(c) Canada prices its electricity exports at the highest price which is competitive with United States generating alternatives. Since these prices are based on the buyer's avoided costs and not the seller's cost of production, this makes Canadian electricity exports very profitable, particularly in the case of cheaply produced hydropower. If American generation costs were to rise due to acid rain legislation, Canadian electricity prices and profits would rise accordingly and dramatically.

(d) Electricity exports help increase Canada's balance of payments surplus with the United States. In April 1983, Canada ran up a $1.99 billion (Canadian) trade surplus, a record for any month. With 70 percent of Canada's foreign sales coming from the United States, increasing electricity exports adds to the surplus and supports the weak Canadian dollar.

Increasing electricity exports is obviously in Canada's economic interest.

2. The Canadian Employment Situation

As demonstrated by the Canadian Energy Research Institute study, additional electrical exports would create significant new employment in Canada. See Appendix II. This comes at a time when Canadian unemployment is particularly high.

More to the point, however, is Canada's desperate need to find sales for its CANDU nuclear reactors. Currently, the Canadian nuclear industry employs 36,000, but nearly all plants under contract have been constructed. The Canadians have been searching for additional sales as an alternative to the idling of these skilled employees which would result from dismantling the industry. Prime Minister Pierre Trudeau has travelled to Mexico and South Korea in search of sales. Prospective sales to Egypt and Rumania have collapsed. Since Canada has an energy surplus, there is no opportunity for additional domestic construction, unless the electricity is originally dedicated for export to the United States. Without additional reactor sales, all firms in this Canadian industry could be out of business by the mid-to-late 1980's. Canada would then be without the expertise needed to develop the next round of CANDU generators projected for the later 1990's. It is critical for the Canadians to "push hard" now on electrical exports in order to save its CANDU industry before the industry folds and its expertise is dissipated.

Similarly, Quebec is desperately seeking sales of electricity to the United States in order to continue the James Bay project. Hydro Quebec has plunged deep into debt to finance this project and interest payments are projected to top $1 billion annually by 1986, roughly $14,000 for every Quebecer. Success of the project and avoidance of financial collapse now depends on increasing electricity exports to the United States. The James Bay project is as critical to Quebec as the CANDU industry is to Canada as a whole, if not more so. Significant construction business has been generated by the James Bay project, and termination of that construction would be a substantial blow to the Quebec economy.

3. Use of United States' Capital to Develop Canadian Electricity Resources

Canada is an energy rich country with much of it's energy potential untapped. Canada has been unable to develop much of its natural resources without capital from abroad. However, after foreign capital assisted in the development of the oil industry in western Canada, the Canadian government adopted a National Energy Policy ("NEP") in 1981. The NEP was designed to increase Canadian ownership in the oil industry, particularly the share of the federal government, at the expense of foreign interests. There are indications that the Canadians likewise intend to use American capital to develop Canadian electrical resources and then turn those facilities over to supply future Canadian demand.

Several sources have reported Canada's willingness to expand generating capacity for exports to the United States in exchange for assistance for costs of construction and long-term, fixed contracts to assure a steady market. Fewer sources have reported Canada's intention to use the American financed facilities to supply future Canadian demand. Yet, the true motives behind this financing plan have surfaced on occasion. For example, as reported in the Canadian newsweekly Macleans. The new plan may prove to be a cripplingly expensive failure—or a shrewd method of getting the Americans to help pay for part of Canada's future electricity supplies. The program calls for the immediate construction of at least one eastern Canadian CANDU reactor to supply electric power to utilities in the northeastern United States. At some time near the turn of the century the Americans would be cut off, and the reactor's electrical output could be redirected to meet domestic needs.

In James Bay: Twice Over, former Quebec Premier and proponent of the James Bay hydro project, Robert Bourassa discussed the necessity of American investment in the James Bay project. Bourassa noted: We can anticipate that in order to make such investments profitable, American buyers will ask for guarantees concerning the delivery of electricity for periods ranging from ten to thirty years. Such contracts would, however, contain clauses concerning the repatriation of energy to Quebec if needed.

A recent article in Business Week reported that most current export contracts contain such repatriation clauses.

Jean Chretien, Canada's Minister of Energy, recently confirmed the existence of this Canadian policy.

Pre-building export facilities in advance of Canadian need is particularly attractive. It shares the benefits of power with our neighbours in the early years, and then allows Canada to recuperate an effective generating source, already partially paid for, when Canadian needs require it.

There is precedent for Canada's use of this type of reversion. During the 1973-74 Middle East oil embargo, Canada refused to renew a renewable short-term electricity purchase arrangement which led to charges that Canada had reneged on the contract. Canadian officials strongly deny that they reneged. American utility officials still refer to this case as an "unpleasant experience." Canada's incentive to use American capital to develop Canadian resources which will be turned back for Canadian use should not be overlooked. Any policy which encourages greater dependence upon Canadian electricity should be tempered by the fact that the Canadians intend to terminate those exports when it suits their needs.

III. CANADA AND ACID RAIN LEGISLATION

Canada's lobbying for enactment of U.S. acid rain legislation

Canada's marketing efforts to boost its sales of electricity must not be examined in a vacuum. Over the last few years, Canadian officials have waged an expensive publicity campaign to impose acid rain controls upon American coal-fired electric plants. The costs of installing such controls have been estimated from $4-8 billion per year, with significant unemployment resulting from some control options. Before examining how the imposition of acid rain controls would benefit the Canadian electricity industry, it is useful to briefly examine Canada's lobbying efforts on acid rain and the steps Canada has take to control its own emissions. The disparity between Canada's preaching and practice on acid rain controls is the subject for an entire study in itself.

1. Canada's Preaching on Acid Rain

The lead role in Canada's media campaign on acid rain is played by John Roberts, Minister of the Environment. Roberts' continual harping on the issue of acid rain has prompted one Canadian journalist to dub him "The Minister for Acid Rain." Roberts has frequently travelled to the United States to give speeches on acid rain. Robert's main proposal, which he began offering in February, 1982, is that Canada is prepared to reduce SO_2 emissions by 50 percent if the United States also reduces its emissions by 50 percent. If the Canadians are so concerned about acid rain, one wonders why they have not unilaterally reduced their emissions as soon as possible and then demanded that the United States follow suit.

Roberts is not the sole Canadian spokesman to speak in the United States. George Rejhon, Environment Counselor assigned to the Canadian Embassy in Washington, D.C. frequently speaks on acid rain, as does Allan Gotlieb, Canada's Ambassador to the United States. When Roberts is unavailable, Dr. Hans Martin of the Environment Ministry's acid rain project substitutes. Other speakers, including provincial environmental officers, also conduct speaking engagements.

Roberts' Ministry of the Environment has a budget of one million dollars this year to conduct its public awareness campaign on acid rain. This amount is in addition to the $650,000 increase which the Canadian government is spending on general lobbying through its embassy in the United States.

The Canadian position on acid rain is essentially that enough information is known, and has been known for some time, to justify a 50 percent reduction in sulfur dioxide emissions. Any reference to the scientific uncertainty surrounding the formation, transformation and control of acid deposition is dismissed as an "information hoax." It is apparent that the Canadians have adopted highly emotional rhetoric to press their campaign. These sort of appeals and lobbying efforts are obviously aimed at an emotional, rather than an objective, examination of the available scientific evidence.

3. Canada's Practice on Acid Rain

Canada's aggressive, emotion-laden campaign on acid rain might have some merit if the Canadian federal and provincial governments were willing to accept the same degree of controls which they wish to impose on United States. As noted earlier, the Canadians will only implement their 50 percent reduction proposal if the United States agrees to implement the same reduction. In other terms, Canada is merely promising to reduce sulfur dioxide in the future. We can examine Canada's track record of such promises in the past.

The Province of Ontario and Ontario Hydro received much praise for two scrubbers which Ontario Hydro promised to install. After a large electricity export contract with General Public Utilities fell through, Ontario Hydro cancelled its plans to install the scrubbers.[illegible] Several months after the Province of Ontario noisily announced that it had imposed significant emission reductions on Ontario Hydro and that the reduction orders would make Hydro a "clear leader in the forefront of nitrogen oxides pollution control," Ontario quietly relaxed its reduction order on nitrogen oxides.[illegible] A deferral of a pollution control order was recently granted by Ontario to the Algoma Steel Corp. in order to spread the costs of necessary pollution abatement equipment over several years.[illegible]

These type actions are not limited to the Province of Ontario. The federal government's NOx limitations for new passenger cars is 3.1 grams per vehicle mile, allowing over three times the emissions as the American standard. In October, 1981, a Parliamentary Subcommittee states that it was "appalled" at this situation and recommended tightening of those standards.[illegible] As of August, 1983, the standards have not been tightened.

The 1981 report Still Waters, by the Parliamentary Subcommittee on Acid Rain, provided a rare self-examination of the Canadian record on acid rain. The Subcommittee noted that Canada, on a per capita basis, emits more SO_2 than the United States.[illegible] Among the recommendations of the Subcommittee to enable Canada to control its own emissions were:

All conversions of oil-fired electricity plants to coal be carried out using best available emission control technology (i.e. scrubbers).

Ontario Hydro be required to utilize best available control technology at all existing and new coal-fired plants.

The Lingan Generating Station at Cape Breton, operated by the Nova Scotia Power Corporation, be required to utilize best available control technology.

There still are no scrubbers in Canada. In the United States, however, there are 87 scrubbers in place and 22 under construction.[illegible] In March, 1983, the Parliamentary Subcommittee was regrouped in order to press for more action on acid rain. One member noted that the federal and provincial governments in Canada failed to adopt the subcommittee's recommendations and that Canada's track record on acid rain was "abysmal."[illegible] Ordinary Canadians have also noted their government's failure to take serious steps to control emissions even as that government criticizes the United States.[illegible]

There are additional examples of Canadian preaching on acid rain diverging from Canadian practice. The continuation of these actions, contrary to the policy Canada seeks to impose in the United States, only serve to damage Canada's credibility on this issue. The systematic nature of these contradictory actions can only make an objective observer wonder what motivates these actions. Why don't the Canadians practice what they preach?

B. United States' practice on acid rain

Before examining the linkage between Canada's acid rain publicity campaign and additional Canadian electricity exports, it is useful to examine the United States' record on acid rain. Surprisingly, this track record is very good, despite Canadian claims and stories in the news media.

From 1976 to 1980, states in the midwestern United States reduced their SO_2 emissions dramatically.

Table III.—*Percent changes in selected State SO_2 emissions [illegible] from 1976 to 1980*

Alabama	−23
Arkansas	−31
Illinois	−21
Kentucky	−33
Michigan	−36
Minnesota	−23
Ohio	−21
Tennessee	−34
West Virginia	−7

[illegible] E. H. Pechan Associates, "Estimates of Sulfur Oxide Emissions from the Electric Utility Industry," financed by grant from U.S. Environmental Protection Agency, (November, 1982) Vol. I, p. 29-30. Ironically, those "downwind" states, which always complain about midwestern SO_2 emissions, increased their emissions over that same period (Massachusetts +73%, Connecticut +27%, Maine +38%, New Hampshire +60%, Vermont +38%, Rhode Island +73%).

Note: As noted earlier, the United States has installed many scrubbers with more under construction. Canada has no scrubbers.

From 1976 to 1980, emissions of primary sulfate in the United States dipped 30%.[illegible] In 1978, Canadian emissions of primary sulfate were 30% the size of American emissions, even though the Canadian economy and population is roughly ten times smaller than the American economy.[illegible] On a pro rata basis, then, the United States has far superior air pollution controls. The strict American controls on NO_x emissions from new passenger cars were noted earlier. The American public and industries have been bearing the costs of extensive pollution control for years.

Take one electric utility system as an example. From 1973 to 1982, The Cleveland Electric Illuminating Company spent $326 million dollars for capital costs of air pollution controls. This figure does not include cost of operation and maintenance of those controls. The impact of these expenditures was reflected in a 37% reduction in SO_2 emissions from 1973 to 1982.[illegible]

These have not been inexpensive controls and the cost has been borne by the ratepayer. According to the United States Energy Information Administration, typical Ohio electric rates are higher than those in Vermont and Maine and roughly equal to those in the rest of New England. A mere 15 percent increase in Ohio's rates (for acid rain controls demanded by Canada) would make average Ohio rates more expensive than those in all the New England states except Connecticut.[illegible] Put in another context, while Americans are paying higher costs for pollution control, Canada's Minister of Energy is boasting that electricity rates across Canada average only 4 cents per kilowatthour.[illegible]

The United States' record on pollution control is an impressive one. There is something patently unfair about promising to reduce emissions in the future by 50 percent, but only if the United States will reduce emissions by 50 percent (or more in some proposals before Congress), without taking into account the sacrifices and reductions already made by the United States and the American public.

C. Costs of acid rain controls

The acid rain legislation favored by the Canadians and which is before Congress is not inexpensive. The proposals range from requiring SO_2 reductions of 8 million tons to reductions of 12 million tons. The 12 million ton reduction most closely approximates the 50 percent reduction sought by the Canadians.

Various macroeconomic studies have estimated that these proposals will cost from $4-8 billion annually.[illegible] The variance is attributable to differing assumptions as to the method for controlling SO_2 emissions. The lower cost figures, favored by the Canadians and others, generally assume that utilities will switch from high to low sulfur coal. These studies further assume that sufficient quantities of low sulfur coal are available at a reasonable cost, and that the boilers of these plants may burn coal with a lower sulfur content. These studies also assume that states with high sulfur coal will not require the local coal to be burned in order to protect massive employment of high sulfur coal miners.[illegible] The high cost studies generally assume the scrubbers will be the preferred or imposed emission control technology.[illegible]

In an attempt to estimate, as accurately as possible, the costs and rate increases attributable to acid rain legislation the Edison Electric Institute organized a company specific study of 24 eastern electric utilities to analyze the effect of an 8 million ton SO_2 reduction. Some of the results are provided below:

TABLE IV—INCREASE AS PERCENT OF 1982 RATES [illegible]

[illegible]	[illegible]	[illegible]
[illegible] Co	[illegible]	[illegible]
The Southern Co	[illegible]	[illegible]
[illegible] Power Co	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Public Service Indiana	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
Indiana & Michigan (AEP)	[illegible]	[illegible]
Ohio Power Co (AEP)	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

[illegible] The study was compiled and prepared for the Edison Electric Institute by [illegible] Research Associates, Inc., and released on June 28, 1983. Additional results are included in appendix IV.

Obviously, the costs and rate increases would be much higher if the 12 million ton SO_2 reduction requirement is imposed as requested by the Canadians.

No matter which emissions control level and method is selected, it is apparent that the costs imposed upon consumers in the United States will rise significantly, particularly those in the Midwest where most emissions reductions are targeted. This increase in costs and rates will make American coal-fired capacity less competitive to the Canada's electricity imports and will make Canadian electricity more attractive to all United States utilities, even those which distribute electricity generated in coal-fired capacity.

IV. ANALYSIS OF SUGGESTED CONSTRAINTS ON THE INCREASE OF CANADIAN ELECTRICITY EXPORTS

Various studies have identified several "constraints" on the potential increase of Canadian electricity exports. The most ambitious of these studies was performed by Larry Parker, an analyst in energy policy for the Congressional Research Service.[illegible] Mr. Parker's study, entitled "Acid Rain Legislation and Canadian Electricity Exports: An Unholy Alliance?" was released September 15, 1982 (hereinafter referred to as "CRS Study"). It concludes that technical, regulatory and political constraints negate much of the advantage acid rain legislation would give to Canadian electricity producers.

This CRS Study has been cited by the Canadian Embassy as downplaying the linkage between Canadian electricity exports and the Canadian lobbying efforts on acid rain.[82] When these "constraints" are examined in light of Canada's needs and incentives to export electricity, and Canada's shoddy record on acid rain control, the "constraints" become illusory. The fact remains that acid rain legislation would give Canadian electricity producers a significant competitive advantage over American producers.

A. Supply constraint

The most important constraint on the increase of Canadian electricity exports, although not specifically identified in the CRS Study as a constraint, is the potential availability of Canadian electricity for export.[83] The CRS study analysed the costs which acid rain legislation would place on American utilities and the resultant competitive advantage provided to Canadian electricity exports.[84] According to the CRS Study, however, the availability of Canadian hydropower is in doubt. Many Canadian sources anticipate that the "export window" will close sometime in the 1990's.[85]

Assuming that the export window actually will close in the next decade, this fact explains the intensive Canadian effort to impose acid rain controls in the United States as quickly as possible. The sooner acid rain controls are imposed, the more electricity Canada can export before the window closes. Since the Canadian prices are based on the buyer's avoided costs, they are designed to obtain the maximum profit possible, not the largest sales possible. In addition, given the long lead time needed for construction of new facilities, the Canadians would hope to obtain sufficient revenue from several years of sales to the United States before turning the new capacity away from the United States to meet future Canadian demand.

Even while it assumed that the supply of Canadian electricity would be limited, the CRS Study noted that decreased Canadian electricity demand and the construction of power plants dedicated to export could increase the availability of Canadian electricity.[86] Since the release of the CRS Study, both of these factors have moved closer to reality.

Quebec Hydro has reduced its long-range forecast of the annual increase in Quebec's electricity demand from 6.2 percent to an average of 3.7 percent for the period 1980-1998. The significance of this projected reduction was recognized by Quebec Hydro: "These factors have completely changed Hydro-Quebec's position. In the medium term, *Hydro-Quebec will have large electricity surpluses for which it must rapidly find new markets.*" (emphasis added)[87] Other Canadian utilities have recently had to revise their electricity demand growth estimates.[88] These reductions increase the amount of electricity available for export to the United States.

The potential for the construction of Canadian nuclear power plants dedicated to export has been discussed previously, but dedicated hydropower is also a distinct possibility. The James Bay project, recently delayed, could provide up to 10,000 MW of generating capacity for export.[89] Other projects could be accelerated or developed with American capital to produce export electricity.[90]

As for the availability of long-term contracts, it should be recalled that the Canadians have continually offered such contracts and that British Columbia Hydro entered into a 35-year agreement with the City of Seattle.[91] Any doubts over the potential supply of Canadian electricity would be removed by American utilities forced to bid for Canadian power due to the costs imposed by acid rain legislation.

B. Technical constraints

The one actual constraint on increased exports identified by the CRS study is transmission capacity.[92] The CRS Study devoted considerable discussion to the uneconomic aspect of transmitting power through several utilities very far from the border. Yet British Columbia Hydro currently sells power to San Diego Gas & Electric, and to Pacific Power & Light, Southern California Edison, Pasadena Water & Power, and the City of Burbank.[93] Obviously, long distance transmission is not per se uneconomic as concluded by the CRS Study. The MANDAN project, from Manitoba to Nebraska, demonstrates the attractiveness of Canadian power even for American utilities far from the border.

While the CRS Study only analysed sales of Canadian power to the Midwest, the greatest potential for increased Canadian sales is to displace oil-fired capacity in the Northeast and Mideast.[94] The Canadian competition for these sales would be the coal-fired capacity in the Midwest, which would be subject to similar wheeling and transmission distance difficulties as the Canadian utilities. Evidence of the competition between midwestern and Canadian utilities is the fact that the GPU-Ontario Hydro sale was cancelled because GPU was able to obtain surplus power more cheaply from Detroit Edison.[95] This competition was acknowledged recently by the Vice-Chairman of Canada's National Energy Board.[96] In addition, Ohio Edison has recently concluded a ten year contract to supply $400 worth of electricity to General Public Utilities. In May, 1983, Ohio Edison signed a five year contract to supply electricity to Potomac Electric Power Co., in Washington, D.C.[97]

It is important to note that the Canadians do not view limited transmission capacity as a constraint. The Canadians are aggressively marketing their electricity across the United States. Milan Nastich of Ontario Hydro has stated that the only element needed for additional sales is "political will."[98] Nastich has also written in Industry Week that technical obstacles are not "insurmountable."[99] Increased economic incentives, such as higher costs, have a way of changing political will. Apparently, the Canadians are confident that where the political will exists, a way will be found to surmount the "constraint" of limited transmission capacity.

C. Regulatory constraints—Canada

1. Permitting Procedures

The CRS Study briefly discussed the legal authority of the National Energy Board ("NEB") to limit electricity exports through its permitting process. Appendix V lists the exports of electrical power in 1982 licensed by the NEB.[100] The CERI Study indicates that export licenses are issued promptly, with the entire process from application to licensing averaging one year. The CERI Study also notes that the NEB has recently received new powers designed to streamline jurisdictional disputes among the provinces. This new authority should "facilitate a more vigorous electricity export policy."[101] Given Canada's desire to export, the internal Canadian permitting process should not be viewed as a constraint.

2. Environmental Assessment Procedure

The CRS Study discussed the legal framework under which the National Energy Board is required to consider the environmental impacts of new facilities. Had the CRS Study reviewed the NEB's decisions in this area, it would not have considered this a "constraint."

In approving the electricity export application of the New Brunswick Electric Power Commission in 1982, the NEB found that the exports would "result in some increased incremental environmental impact and social costs from increased in-province fossil fuel generation."[102] Yet, since these costs would be "small relative to the value of the exports," the application was approved.[103] The CERI report concluded that the price which could be charged for electricity exports would be "more than sufficient" to cover environmental costs.[104]

Despite concerns expressed by members of Ontario's Parliament and several environmental groups, including the federal Ministry of the Environment, the NEB approved the application of Ontario Hydro to construct a cable under Lake Erie for sales to GPU.[105] In 1982, Ontario Hydro agreed to export $100 million of power and increase its SO_2 emissions by over 37,000 tons without even consulting the Ontario Ministry of the Environment.[106] Obviously, the Canadians pollute when it is profitable to do so.

With this record of addressing environmental concerns, it is clear that environmental considerations will not be a "constraint" on Canadian electricity exports.

3. Pricing Policy

The CRS Study identified the three criteria that an export price must meet under Canadian standards.

(1) It must cover fully the cost of the electricity being exported.

(2) It cannot be less than the price Canadians pay for comparable service.

(3) It cannot be materially less than the least-cost alternative to the United States utility.[107]

The first two times will be easily met by any proposed sale because the Canadians do not price their electricity exports on a cost generated basis. The third requirement likewise is of little importance since NEB officials state that a sale will usually result if a utility in the United States can save two-tenths of a cent per kWh.[108] The Price is usually set at 80% of the buyer's avoided cost.[109] The higher the cost of United States generating capacity, the more likely that these requirements will be met.

4. Acid Rain Reduction Requirements

The CRS Study contained a lengthy discussion of Canadian acid rain requirements and concluded that those requirements would increase the cost of Canadian coal-fired capacity "in a fashion similar to that which would occur to U.S. coal-fired capacity."[110]

Since the overwhelming amount of proposed export electricity is hydro or nuclear generated, this constraint is illusory. Even in 1982 a full 80 percent of the exported electricity came from hydro generators.[111]

D. Regulatory constraints—United States

The CRS Study briefly discussed the federal permitting process as a "constraint" and accurately noted that permits are required only for additional construction, but not for additional sales over existing lines.[112] The General Accounting Office report, "Clear Federal Policy Guidelines Needed for Future Canadian Power Imports," was released at the same time as the CRS Study and examined this issue in depth. The GAO made these findings, among others:

(1) The Department of Energy (responsible for federal permitting in this area) has no direction on how to fulfill its permitting responsibilities and thus has no specific set of criteria to conduct its reviews.

(2) The Department of Energy current policy is to place no prescribed limits on Canadian electricity imports.

With these policies in effect, CRS cannot credibly identify federal regulatory procedures as a "constraint."

The CRS Study also discussed several other federal and state laws, particularly siting requirements with which a new transmission line must comply. While these laws may constrain imports of Canadian electricity, they also apply to and constrain construction of new transmission lines from existing capacity in the United States and the construction of new capacity in the United States. Since these laws apply across the board, their impact should not be considered a special constraint on Canadian electricity exports.

E. Political constraints

The "political constraints" identified by the CRS Study are a euphemistic method of saying that certain groups will oppose the export and import of Canadian electricity and may put pressure on the regulatory process to delay approvals in anticipation of preventing export sales. The Canadian incentives discussed previously will probably keep the Canadian dissent in check while the Canadian marketing campaign in the United States will encourage American utilities to deal with any opposition.

The most serious political constraints on Canadian electricity exports are those raised in the political battle over the imposition of acid rain controls. Since it is clear that acid rain legislation would greatly enhance the competitive advantage of Canadian electricity exports, the political opposition to acid rain controls becomes *de facto* political opposition to Canadian electricity exports.

F. Summary—The CRS study refuted

The CRS Study analyzed three ways in which restrictive acid rain legislation would increase the demand for Canadian electricity. They are:

(1) discourage use of coal-fired capacity,

(2) discourage oil to coal conversions,

(3) discourage the building of new coal-fired capacity.

The CRS Study overlooked a fourth development: acid rain legislation as proposed by the Canadians would eliminate midwestern coal-fired capacity as competition for displacing oil-fired capacity in the Northeast and Mideast. As noted earlier, midwestern coal-fired utilities have provided stiff competition to Canadian utilities.

The CRS Study admitted that the three developments would result from acid rain legislation and would encourage the demand for Canadian electricity but that electricity exports would not increase due to the constraints previously discussed. As demonstrated, these "constraints" lack the ability to constrain anything; therefore, the proposition that acid rain legislation will encourage the export of Canadian electricity is valid.

V. IMPACT OF ACID RAIN LEGISLATION ON CANADIAN ELECTRICITY EXPORTS

A. The Canadian linkage of electricity exports to acid rain legislation

Beyond the apparent fact that Canada would profit by the adoption of tighter acid rain controls in the United States, there is evidence that the Canadians publicly recognize the profit in the linkage between the two issues.

First, the Canadian National Energy Board considers the possibility of displacing capacity in the United States when it considers applications for export. In discussing the environmental considerations weighed by the NEB before approving an export application of Ontario Hydro, the NEB found that the export would not result in a net increase in emmissions in Canada except, possibly, in 1985. It was also expected that the export would displace U.S. generation resulting in a decrease in emissions there.

Second, after General Public Utilities cancelled the proposed purchases from Ontario Hydro, Ontario Hydro cancelled the two scrubbers which it had planned. Rather than install the scrubbers to decrease emissions in the "sensitive" Province of Ontario, Hydro opted to save $240 million and continue emissions at higher levels.

Third, Arthur Porter, former chairman of the Royal Commission on Electric Power Planning, has publicly called for construction of a nuclear plant for export to the United States in order to reduce the United States' reliance on coal fired generating stations and to turn a $150 million profit.

Fourth, in his book *James Bay Twice Over*, former Quebec Premier Robert Bourassa linked Canadian acid rain efforts with the benefits of the James Bay hydro project. Bourassa stated:

> Replacing thermal energy by Quebec hydroelectricity in Quebec's neighboring areas will considerably decrease polluting fallout, namely, acid rain, in these regions as well as in Quebec. . . . It is not only useful to increase the capacity of interconnections, but also necessary to study the means of increasing electricity exports so that both Quebec & Quebecers can profit without making any sacrifices.

Certainly, a plan to increase American demand for Quebec power would make it easier to secure American capital for the James Bay project and make Quebec a profit without sacrifices.

Despite all protestations, Canadians do see the financial profit to be gained from increased electricity exports and the displacement of capacity in the United States.

B. National policy considerations of increased dependence on Canadian electricity

There are several national consequences to the acceptance of increased Canadian power exports which should be carefully evaluated before acid rain legislation is adopted. First, employment and income would be lost. Since one of the Canadian goals is to increase Canadian employment and income, such increases must come from the United States. Every dollar sent to Canada for hydro or nuclear energy means income lost in the United States and jobs lost for American workers in mining, utility and related industries. Even where the Canadian electricity is generated from coal mined in the United States, the income effects, if not the unemployment effects, are felt. At a time when the unemployment in the United States is at record levels and the United States is running a record trade deficit with Canada, any program which would export jobs and income to Canada should be carefully examined.

Second, accepting imports would increase the dependence of the United States upon another foreign source of energy and threaten reliability of the electric utility industry in the United States. The United States is beginning to achieve independence from foreign oil, but increasing electricity imports from Canada would be a step backward. The GAO report, "Clear Federal Policy Guidelines Needed for Future Canadian Power Imports" analyzed this issue closely. The GAO reported that three councils of the North American Electric Reliability Councils felt that the eastern U.S. could withstand losses of imported Canadian power up to 2,400 MW and possibly 3,700 MW during light load periods. The three councils could not withstand a 3,700 MW loss during heavy period. The New England Power Pool (NEPOOL) felt that a loss of 2,000 MW alone would put a strain on the spinning reserves available within the region and the ability of neighboring systems to help during NEPOOL's shortfall.

There should be serious doubt as to Canada's willingness to honor long-term commitments to supply electricity. Canada's intention to terminate American exports when Canadian demand rises was discussed earlier. Moreover, the legal maneuvering of Newfoundland to break its long term contract with Quebec casts doubt upon the willingness of the Canadian provinces to live with the contracts they sign.

There is also serious doubt as to Hydro Quebec's ability to produce reliable amounts of electricity. On December 14, 1982 a blown transformer threw the entire province of Quebec into a blackout for 12 hours. In 1981, energy consultant Amory Lovins had written a memorandum to the New England utility commissioners warning about the susceptibility of Hydro Quebec's grid system to power failures. The same fears were also expressed to the annual Canadian Nuclear Association conference in Montreal in June, 1983. The issue of overdependence and jeopardized reliability cannot be taken lightly.

Third, a special danger exists in the large scale purchase of Canadian nuclear power. A combination of factors make this scenario likely to occur.

These factors are: (1) the stressed state of the U.S. nuclear industry in the United States, (2) Canada's need to maintain the CANDU nuclear industry, (3) the Canadian willingness to construct nuclear plants dedicated for export to the United States, (4) acid rain legislation which makes coal-fired generation in the United States economically unattractive and investment in Canadian power plants attractive. The only missing factor is the United States acid rain legislation and the Canadian government is lobbying vigorously for such restrictions.

Moreover, this situation might be beneficial, aside from the energy dependence issue, if the Canadians would be responsible for the hazards of the nuclear generation. Yet, it is likely that the United States will be the depository for much of the nuclear waste generated in Canada. Already, nuclear waste from Canadian reactors is shipped to the United States. Under this likely scenario, the U.S. would have all the hazards and expenses of nuclear generated power, yet would not have the job, the income and, more importantly, the control of the electricity generating facilities.

These considerations are all costs which must be factored into the cost/benefit equation for acid rain legislation. The wide divergence between Canada's preaching and practice on acid rain and the numerous incentives to export additional electricity should cause the United States to examine Canada's lobbying efforts in a critical manner. A failure to carefully examine Canada's interests in this issue would be a poor reflection on those who would adopt acid rain legislation.

VI. CONCLUSION

Before enacting acid rain legislation, if it should be proven to be needed at all, Congress should examine the economic and national security aspects of vastly increased imports of Canadian electricity. Since acid rain legislation will have the effect of providing Canada's electric utilities with a competitive advantage over utilities in the United States, Congress should consider:

(1) Enactment of a clear federal policy limiting Canadian electricity imports. These limits should be sufficient to protect the reliability of the electricity supply in the United States and to protect American workers and companies from losses of jobs and income.

(2) The environmental impact of massive imports, particularly the necessity to construct additional transmission capacity. The fact that the United States may become the depository for Canada's nuclear waste should be examined.

(3) The regulation of pricing of Canadian electricity imports including the possibility of an excise tax to negate much of the competitive advantage which acid rain legislation on controls would give Canadian electricity producers.

Canada's economic interest in increasing electricity exports to the United States is very clear. Any policy or legislation which would tend to increase those exports should be reviewed to determine if the economic and national interests of the United States are being protected.

FOOTNOTES

[1] Canada's Minister of the Environment, John Roberts, has called this connection "nonsense." UPI Release, October 24, 1981.

[2] U.S. Department of Energy and the Ministry of Energy, Mines and Resources Canada, *Electricity Exchanges*, Minister of Supply and Services Canada, May 1979, p. 39.

[3] See footnote to table I.

[4] See footnote to table II.

[5] Canadian Energy Research Institute, *Potential Benefits and Costs of Canadian Electricity Exports*, December 1982, Vol. I, p. xii (hereinafter cited as "CERI Report").

[6] Holmes, P. A. "Pushing to Peddle Canadian Power," "*Fortune*," September 20, 1982 citing Richard Pouliot of Quebec's Ministry of Energy.

[7] General Accounting Office, "Clear Federal Policy Guidelines Needed for Future Canadian Power Imports" (September 20, 1982) p. 1 (hereinafter cited as "GAO Report").

[8] Ministry of Energy, Mines and Resources, Canada, *Electric Power in Canada*, 1979, p. 34. Canadian National Energy Board, *1982 Annual Report*, p. 36.

[9] *GAO Report*, supra note 7, p. 4.

[10] "B. C. nets huge sale in hydro deal with U.S.," *Toronto Star*, April 15, 1983, p. A9.

[11] Address by Marc Lalonde, Canadian Minister of Energy, Mines and Resources, to the National Governors' Conference, Afton, Oklahoma, August 9, 1982.

[12] Royal Commission on Electric Power Planning, *Concepts, Conclusions and Recommendations*, Vol. I, pp. 106, 148-49 (February, 1980).

[13] "Build nuclear plant to sell U.S. power, Ontario told," *Toronto Star*, October 25, 1981, p. A22.

[14] Robert Bourassa, James Bay Twice Over, (March, 1981) Excerpts translated by Brigette Rosenberg from book published in French (hereinafter cited as "*James Bay*").

[15] *Id.*

[16] *CERI Report*, supra note 5, pp. 119-120.

[17] Address by Marc Lalonde, Canadian Minister of Energy, Mines and Resources, to the National Governors' Conference, Afton, Oklahoma, August 9, 1982.

[18] "We've more power, gas to sell, Lalonde tells United States," *Toronto Star*, June 24, 1983, p. C3.

[19] Address by Jean Chretien, Minister of Energy, Mines and Resources, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[20] "Ontario: Powerhouse for United States," *Toronto Star*, December 13, 1981, p. C1.

[21] "Power Sale Studied", *Toronto Star*, August 25, 1981. Press Release, New Jersey Board of Public Utilities, August 20, 1981.

[22] The MANDAN project was delayed last year by a South Dakota court, but the MANDAN sponsors are pushing on. UPI Release, October 6, 1982.

[23] *EIA Report*, supra note 3, p. 66.

[24] "Nuclear power worth billions: Ontario Hydro," *Toronto Star*, October 4, 1981, p. A19. Ironically, in February, 1983 Environment Minister John Roberts stated that all that was needed to resolve the acid rain issue was "political will." "Roberts warns United States journalists on acid rain," *Toronto Star*, February 26, 1983, p. A1.

[25] Address by Hugh Macaulay, Chairman of Ontario Hydro, "International Energy Sales—Sensitivity versus Benefits" delivered to the Canadian German Chamber of Industry and Commerce, June 15, 1982.

[26] *Wall Street Journal*, December 9, 1981, p. 34.

[27] UPI release, June 11, 1982.

[28] UPI release, June 30, 1983.

[29] UPI release, October 12, 1982.

[30] Hydro-Quebec, *Hydro-Quebec Development Plan 1983-1985: A Synopsis*, October, 1982, pp. 11, 15.

[31] These were briefly discussed in somewhat different form in the *EIA Report*, supra note 3, p. 13.

[32] Canadian National Energy Board, *1982 Annual Report*, p. 97.

[33] *CERI Study*, supra note 5, p. 117.

[34] Address by R. F. Brooks, Vice Chairman of the Canadian National Energy Board, before the Canadian Nuclear Association International Conference, Montreal, Quebec, June 14, 1983.

[35] "U.S. Export Ban Would Cost us Billions: Hydro," *Toronto Star*, February 12, 1982, p. A8.

[36] UPI Release, June 28, 1981. "The Newfoundland-Quebec power battle," *Toronto Star*, June 19, 1983, p. F7.

[37] UPI Release, June 21, 1983.

[38] *EIA Report*, supra note 3, p. 30.

[39] "Canada Trade Surplus Totaled $1.99 Billion in April for a Record," *Wall Street Journal*, June 9, 1983, p. 36.

[40] Canadian unemployment recently reached 1.58 million. Over 300,000 Canadians joined the welfare rolls between March 1982 and March 1983. "Out of Work," *Macleans*, April 4, 1983, pp. 30-38.

[41] "One More Push to Rescue CANDU," *Macleans*, October 11, 1982, p. 50.

[42] "Trudeau in South Korea to seal Candu reactor sale," *Toronto Star*, September 28, 1981, p. A14. "Thousands of high tech jobs hinge on Candu sale to Mexico," *Toronto Star*, December 13, 1981, p. E3.

[43] "One More Push To Rescue Candu," *Macleans*, October 11, 1982, p. 50.

[44] *Id.*, p. 52.

[45] Address by Jean Chretien, Minister of Energy, Mines and Resources, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[46] A recent editorial in the *Toronto Star* also exhorted Canadians to "push hard" on acid rain to get restrictive controls imposed in the United States. "Let's push hard on acid rain," *Toronto Star*, June 4, 1983, p. B2.

[47] Asinot, Richard, "Deluge," *Environmental Action*, March, 1983, pp. 13, 18.

[48] *Id.*, at p. 10.

[49] Address by G. W. Nichols, New England Electric System, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[50] For example, see "Canadian Electricity May Be Cheaper, But It Doesn't Come Free of Problems," *National Journal*, May 22, 1982, p. 910. Address by Marc Lalonde, Minister of Energy, Mines and Resources to National Governors Association, Afton, Oklahoma, August 9, 1982. Address by Jean Chretien, Minister of Energy, Mines and Resources, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[51] "One More Push to Rescue Candu," *Macleans*, October 11, 1982, p. 50.

[52] *James Bay*, supra, note 14.

[53] "The U.S. Plugs into Canadian Power," *Business Week*, May 23, 1983, p. 188.

[54] Address by Jean Chretien, Minister of Energy, Mines and Resources, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[55] Letter from Mark D. Segal, Canadian Ministry of Energy, Mines and Resources, reprinted in *GAO Report*, supra, note 7, p. 66.

[56] Address by G. W. Nichols, New England Electric System, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[57] Frothingham, Allan, "The Liberals Sniff the Wind," *Macleans*, July 4, 1983, p. 56.

[58] "Canada will cut acid rain 50 percent if U.S. does same," *Toronto Star*, February, 1983, p. A4.

[59] UPI Release, October 30, 1981. Part of this public awareness campaign apparently involved the widespread distribution of the Canadian "propaganda" movies on acid rain.

[60] "Canada Tries To Organize Lobby in U.S.," *Wall Street Journal*, April 12, 1983. "Now we're joining the lobbying game," *Toronto Star*, April 23, 1983, p. B6.

[61] Address by John Fraser, former Minister of the Environment, to the Izaak Walton League, June 15, 1982. Any request for further information to buttress the Canadian position has been termed "foot-dragging." "U.S. stalling on acid rain Roberts says," *Toronto Star*, June 16, 1982, p. A24.

[62] Even the Canadian scientific research on acid rain appears geared to headline hunting and public relations gimmicks rather than answering the genuine uncertainties which surround the acid rain issue. See, for example, "Rabbits sprayed with acid rain in test," *Toronto Star*, April 22, 1982, p. A11. In this test the rabbits' eyes were sprayed directly with concentrated acids in excess of those found in nature.

[63] "Ontario Hydro Set to Shelve Major Anti-Pollution Project," *Toronto Globe & Mail*, July 30, 1982, p. 1.

[64] "Ontario lifts controls on Hydro pollutants blamed for acid rain," *Toronto Star*, February 3, 1982, p. A18.

[65] "Pollution Deferral Given," *Toronto Star*, June 10, 1983, p. A7. The actions of the Province of Ontario are similar to the contradictory actions of the State of New Hampshire. In March, 1983 over 190 town meetings in New Hampshire endorsed a resolution calling for a 50 percent reduction in sulfur dioxide emissions. (Canada's John Roberts identified these votes as an "encouraging" sign in a speech to the Parliamentary Committee on Acid Rain on June 21, 1983.) In April, 1983 the U.S. Environmental Protection Agency began a public comment period on a request by the State of New Hampshire to double its sulfur-in-oil content limitation. 48 Fed. Reg. 12100 (March 23, 1983).

[66] Parliamentary Subcommittee on Acid Rain, *Still Waters*, October, 1981, p. 47.

[67] *Id.*, p. 19.

[68] "U.S. taunts Canada on acid rain record," *Toronto Star*, February 11, 1982, p. A19.

[69] "MPs vow they'll play 'hardball' to stop acid rain," *Toronto Star*, March 18, 1983, p. A19.

[70] "Ottawa now gets blame for acid rain," *Toronto Star*, November 21, 1981, p. B5.

[71] See footnotes to table III.

[72] United States Environmental Protection Agency, *The Acidic Deposition Phenomenon and Its Effects: Critical Assessment Review Papers*, Public Review Draft (June, 1983), Vol. I, p. 2-76.

[73] *Id.*, U.S.-Canada Memorandum of Intent, Working Group 3B, Final Report, *Emissions, Costs and Engineering Assessment* (June, 1982), p. 100.

[74] Communication from official at The Cleveland Electric Illuminating Company.

[75] U.S. Energy Information Administration, *Typical Electric Bills*, January 1, 1982, p. 15.

[76] Address by Jean Chretien, Minister of Energy, Mines and Resources, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[77] A chart of these studies is contained in Appendix III.

[78] A study by the Congressional Research Service estimated that the total job loss in Ohio due to fuel switching in order to comply with an 8 million ton SO_2 reduction would be between 19,200 and 31,000. In some hard hit counties, the unemployment rate would rise to the 20 percent—25 percent range. Parker, Larry, "Mitigating Acid Rain: Implications for High Sulfur Coal Regions," May 19, 1983.

[79] It should not be assumed that the high cost studies, which entail high electricity rate increases, will not result in higher unemployment even though the jobs of high sulfur coal miners will be protected. The higher electricity rates will significantly raise costs of the manufacturing industries of the Midwest, still struggling to recover from the recent recession. The study has not yet been completed which projects the job losses due to higher electricity rates in the Midwest.

[80] See footnote to table IV.

[81] Larry Parker has written extensively on the acid rain and related issues. In the past year, at least the following studies have been released by the Congressional Research Service under Mr. Parker's name.

(1) "Distributing Acid Rain Mitigation Costs: Analysis of a Three-Mill User Fee on Fossil Fuel Electricity Generation," April 11, 1983.

(2) "Mitigating Acid Rain: Implications for High-Sulfur Coal Regions," May 6, 1983.

(3) "Impact of Proposed Acid Rain Legislation on the Illinois Coal Industry," February 21, 1983.

(4) "Summary and Analysis of Technical Hearings on Costs of Acid Rain Bills," July 26, 1983.

[81] "Opportunities for Increased Control of Nitrogen Oxides Emissions from Stationary Sources: Implications for Mitigating Acid Rain." December 9, 1982.

[82] See letter from George Rejhon, Environment Counselor, Canadian Embassy, to Senator Larry Pressler, Chairman, Senate Subcommittee on Arms Control, Oceans & International Operations, and Environment, October 5, 1982.

[83] *CRS Study*, pp. 6-9, 30-35.

[84] *CRS Study*, pp. 24-29.

[85] "One More Push for Candu," *Macleans*, October 11, 1982, p. 50.

[86] *CRS Study*, p. 8.

[87] Hydro Quebec, *Hydro Quebec Development Plan 1983-1985: A Synopsis*, p. 2.

[88] *EIA Report*, supra note 3, p. 35.

[89] *James Bay*, supra note 14.

[90] See *CERI Study*, supra note 5, pp. 47-51. Proposed additions to Canadian generating capacity through 1990, even without dedicated exports, total over 20,000 MW. *Id.* at p. 80.

[91] "B.C. nets huge sale in hydro deal with U.S.," *Toronto Star*, April 15, 1983, p. A8.

[92] *CRS Study*, pp. 9-14.

[93] *EIA Report*, supra note 3, p. 66.

[94] *CERI Report*, supra note 5, p. 111. Address by Robert A. Hiney, Senior Vice President, New York Power Authority, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 13, 1983.

[95] Address by Hugh Macaulay, Chairman Ontario Hydro, "International Energy Sales: Sensitivity versus Benefits," delivered to the Canadian German Chamber of Industry and Commerce June 15, 1982.

[96] Address by R. F. Brooks, Vice-Chairman, Canadian National Energy Board, to the Canadian Nuclear Association International Conference, Montreal, Quebec, June 14, 1983.

[97] "Ohio Edison to sell excess power to GPU," *Cleveland Plain Dealer*, July 7, 1983, p. 1C.

[98] "Nuclear power worth billions, Ontario Hydro," *Toronto Star*, October 4, 1981, p. A19.

[99] Nastich, Milan, "Canadian Energy could lessen U.S. oil dependency," *Industry Week*, October 4, 1982, p. 13.

[100] Canadian National Energy Board, *1982 Annual Report*, Appendix E-V.

[101] *CERI Report*, supra note 5, p. 32.

[102] *CRS Study*, pp. 16-17.

[103] Canadian National Energy Board, *1982 Annual Report*, p. 60.

[104] *CERI Report*, supra note 5, p. 114.

[105] Canadian National Energy Board, *1982 Annual Report*, p. 41. "Hydro plan will double sulphur in air: Ottawa," *Toronto Star*, February 12, 1982, p. A8. "300 lakes will die if Hydro plan to export power proceeds—Capps," *Toronto Star*, December 10, 1981, p. A 13. "Hydro's energy plan would kill 300 lakes, critics charge," *Toronto Star*, February 5, 1982, p. A3.

[106] "Hydro deal will kill 26 lakes, MPP says," *Toronto Star*, April 16, 1982, p. A12.

[107] *CRS Study*, p. 17.

[108] *GAO Report*, supra note 7, p. 9.

[109] *EIA Report*, supra note 3, p. 10.

[110] *CRS Study*, p. 19. That is assuming that the Canadians stick to their proposed requirements. For example, Ontario Hydro has cancelled two planned scrubbers and the Province of Ontario has relaxed stringent NO_x requirements on Ontario Hydro. "Ontario Hydro Set to Shelve Major Anti-Pollution Project," *Toronto Globe & Mail*, July 30, 1982, p. 1. "Ontario lifts controls on Hydro pollutants blamed for acid rain," *Toronto Star*, February 3, 1982, p. A18. A deferral was recently given to the Algoma Steel Corp. in order to spread the costs installing necessary pollution abatement equipment over several years. "Pollution Deferral Given," *Toronto Star*, June 10, 1983, p. A7.

[111] Canadian National Energy Board, *1982 Annual Report*, p. 37.

[112] *CRS Study*, p. 20.

[113] *GAO report*, supra note 7, pp. 23, 26.

[114] An ordinance has recently been submitted in Cleveland City Council to authorize Cleveland Municipal Power to purchase electricity from Ontario Hydro instead of electricity produced by nearby coal fired plants.

[115] The *CERI Study* and others have targeted U.S. oil fired capacity as the most likely target for displacement. See previous discussion under "Transmission Constraints."

[116] Canadian National Energy Board, *1982 Annual Report*, p. 41.

[117] "Ontario Hydro Set to Shelve Major Anti-Pollution Project," *Toronto Globe & Mail*, July 30, 1982, p. 1.

[118] "Build nuclear plant to sell U.S. power, Ontario told," *Toronto Star*, October 25, 1981, p. A22.

[119] *James Bay*, supra note 14.

[120] *GAO report*, supra note 7, pp. 10-11.

[121] *GAO report*, supra note 7, p. 11.

[122] Asinof, Richard, "Deluge," *Environmental Action*, March 1983, p. 14.

[123] *Id.* at p. 12.

[124] "Northern U.S. States hungry for Canadian power," *Toronto Star*, June 27, 1983, p. C9.

[125] "Our atomic waste feared in U.S.," *Toronto Star*, March 5, 1983, p. A12; Hoffman, Abbie, "Nuclear Waste Upstate," *New York Times*, September 27, 1982, p. A15.

Mr. **FORD**. Mr. President, I have not included the appendix of this report in order to cut down the number of pages in the RECORD. But I do encourage my colleagues to take the opportunity ro read this most informative report.

I thank the Chair and I yield the floor.

CARL SAGAN ON THE CONSEQUENCES OF NUCLEAR WAR

Mr. **PROXMIRE**. Mr. President, few persons and no Members of Congress can speak with more authority on the consequences of nuclear war than Carl Sagan, the eminent scientist. Yesterday—October 30, Parade magazine carried an article by Dr. Sagan that spells out more vividly and expertly than I have ever seen it before, what nuclear war would bring.

As Sagan writes—no one can foresee for sure what would happen once nuclear war breaks out but in Sagan's view it could be far worse than anything we have envisioned to date. We all know that nuclear arsenals presently in being, contain the equivalent of thousands of pounds of dynamite for every man, woman, and child on Earth. I have pointed out on the floor before that the World Health Organization estimates that in an all out nuclear war between the United States and the Soviet Union a billion persons would die and another billion would be grievously wounded, that little or no medical help would be available for the wounded. They too would die and die agonizing deaths. Sagan recognizes all of this but then adds: "Unfortunately, the real situation would be much worse." How could anything be worse?

Sagan explains this. He argued that: "In technical studies of the consequences of nuclear weapons explosions, there has been a dangerous tendency to underestimate the results." He documents this with an analysis of nuclear explosions over the past 30 years. He then describes how he and a group of other scientists calculated the consequences of a 5,000-megaton war—we and the Soviet Union have 13,000 megatons; this would only be a part of our arsenal—on two natural phenomena:

First, sunlight on the Earth and;

Second, the temperature of the Earth.

Sagan describes the result as "horrifying." If anything that is an understatement.

The amount of sunlight would be reduced to a few percent of normal, so dark that plants could not live. This would persist for weeks. Much more spectacular were the estimates of these scientists on the effect of such a nuclear war on the temperature of the Earth. They found that temperatures—except for narrow strips of coastline—would drop to 13° below zero Fahrenheit and stay below freezing for months. And Sagan says he and his other experts may have underestimated how long the cold and dark would last. And we would suffer the cold and dark with little or none of the light or heat that comes from our big utility plants, they would die with our cities. Aside from the miserable struggle to exist in the cold and dark, the real disaster would come from starvation. Virtually all crops and farm animals would be lost—certainly in the United States and in the rest of the Northern Hemisphere. As Sagan writes: "Most of the human survivors would starve."

Mr. President, I hope and pray that we can find some way to bring this message to all Members of Congress. I am convinced that our biggest problem in stopping this arms race is the refusal of too many of our policymakers to look squarely and fully at reality. We still stumble along with many Americans, including some Senators and Congressmen and some members of this administration and more than a few widely read commentators, arguing that somehow we can win an arms race and in the process forestall a nuclear war. The administration's proposal to vastly step up the nuclear arms race in space represents an example of this. Unless we achieve arms control measures much more far reaching than anything yet proposed, we will spend $64 billion next year fattening up our nuclear arsenal and $450 billion over the next 6 years exclusively for more nuclear arms. The Russians will also spend hundreds of billions. Other nations will also work hard to get in the nuclear arms act. And as the nuclear arms technology races on, these other nations will find it cheaper and easier to join the nuclear club. Research, and development by the superpowers in nuclear arms relentlessly spills over to the rest of the world community, until somehow, somewhere through design or error, nuclear war will start. It is true that nuclear war is not likely to start with a planned, premeditated attack by one superpower on the other. Such an initiative would be an act of suicide. But as I have said on the floor previously, we have hundreds of fingers on the nuclear trigger in spite of the most comprehensive effort to centralize the nuclear decision in the hands of the President. The Russians too have many fingers on the trigger. Somewhere, somehow, sometime, someone will press the trigger. And then?

Every year more and more nations seek and some will find a way to build up their own nuclear war capability. Once a nuclear war starts, can we con-

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April 1, 1984, Sunday, Late City Final Edition

SECTION: Section 1; Part 1; Page 4, Column 1; Foreign Desk

LENGTH: 641 words

HEADLINE: ACID RAIN STUDIES LAPSE IN CANADA

BYLINE: By DOUGLAS MARTIN

DATELINE: TORONTO, March 31

BODY:

At a time when the Canadian Government has been sharply critical of what it regards as United States inaction on curbing acid rain, it appears to be letting several major research efforts of its own lapse.

For the fiscal year beginning Sunday, the Government has not set aside money for research on acid rain's effects on human health, or provided for more research on how lakes and other bodies of water become acidified.

These actions could be reversed later in the year, and appear to be the responses of particular agencies to fiscal pressures, more than policy shifts. But Canadian environmentalists have expressed concern that their Government's efforts to persuade Washington to do more to reduce acid rain might be hampered by the decisions.

The Reagan Administration decided this year to limit its spending on acid rain to doubling reseach expenditures to $55.5 million, an action that prompted a note of diplomatic protest from Canada last month.

U.S. Response to Protest

On Friday the United States responded to the Canadian protest with a note of its own, reportedly arguing that action to curb acid rain must be delayed until more research is done. The issue is expected to be discussed by Secretary of State George P. Shultz and the Canadian Secretary of State for External Affairs, Allan J. MacEachen, when they meet Sunday and Monday in Washington.

Ottawa has consistently agreed that more research is needed on acid rain, which is precipitation that has been polluted by exhaust emissions in the air

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that eventually fall back to earth, damaging the environment and contaminating the water supply.

But despite the agreement that research is needed, the Canadian Government believes enough is already known to begin spending money to reduce emissions of the sulfur dioxide gas known to cause acid rain. The issue is a principal irritant between Canada and the United States, because American cooperation is needed to stem emissions that now drift north and fall on Canadian soil.

''The support appears to be dribbling away,'' said Michael Perley, a director of the Canadian Coalition on Acid Rain. ''It's not helpful scientifically and it's not helpful politically.''

Research Budget Cuts

Officials in the Ministry of the Environment, which has headed the Canadian acid rain effort, are privately displeased with the budget decisions made by other ministries. The health research cuts come out of the Ministry of Health and Welfare's budget, while aquatic research, which has also not yet been financed, is done by the Fisheries Ministry.

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The Department of Transportation has not proposed a program to curb the nitrous oxide emissions from vehicles that are believed to contribute to acid rain. Research on acid rain's impact on forests had not been included even in past budgets. Still, Robert W. Slater, assistant Deputy Minister of Environment, said that evaluation of existing data will continue, and that more will eventually be collected, as economic conditions allow. Canada's budget deficit is estimated at nearly $30 billion, a record high, and all public expenditures are under close scrutiny.

''There is certainly no question of our commitment,'' Mr. Slater said. ''We're in this long-haul, ad infinitum.''

One of the most visible cuts was an experiment begun last fall to monitor groups of children in two similar towns in Ontario, where acid rain is known to fall, and in Manitoba, where the rain is far less acidic.

In addition, Canada's major effort to study the aquatic effects of acid rain, which includes such sophisticated experiments as artificially acidifying an Ontario lake, has still not been funded. That program has spent about $5 million yearly for the past four years, and officials are said to be seeking funds from other areas to continue it.

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SUBJECT: Terms not available

LEVEL 1 - 72 OF 109 STORIES

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April 4, 1984, Wednesday, Late City Final Edition

SECTION: Section C; Page 17, Column 1; Cultural Desk

LENGTH: 232 words

HEADLINE: 'PROPAGANDA' LABEL UPHELD ON 3 FILMS

BYLINE: AP

DATELINE: WASHINGTON, April 3

BODY:

A Federal judge today dismissed a lawsuit that sought to block the Justice Department from classifying three Canadian films on acid rain and nuclear war as ''political propaganda.''

The judge, Charles R. Richey, said that the distributors of the films, who filed the suit, failed to show that they were or would be injured by the classification.

''The court can find no allegations of fact that would indicate that audiences have diminished or that citizens are not seeing the films because of the 'political propaganda' classification,'' Judge Richey said in a 26- page opinion.

He also said the record indicated that the Justice Department did not accuse the distributors of disseminating communist propaganda, as the distributors had contended.

In January 1983, the Justice Deparment's Internal Security Section ruled that the films constituted ''political propaganda.'' A 40-year- old Federal law requires any film sent to this country by a registered foreign agent - such as the National Film Board of Canada - to be labeled if it engages in political advocacy. The department said the films, when shown to American audiences, must carry the classification.

The action was taken against '' Acid Rain: Requiem or Recovery'' and ''Acid From Heaven.'' The third film, ''If You Love This Planet,'' about the consequences of nuclear war, has been nominated for an Academy Award.

SUBJECT: MOTION PICTURES; ACID RAIN; SUITS AND CLAIMS AGAINST GOVERNMENT; PROPAGANDA; MOTION PICTURES; MOTION PICTURES; ATOMIC WEAPONS; MOTION PICTURES

ORGANIZATION: JUSTICE, DEPARTMENT OF

NAME: RICHEY, CHARLES R (JUDGE)

TITLE: ACID RAIN: REQUIEM OR RECOVERY (MOVIE); ACID FROM HEAVEN (MOVIE); IF YOU LOVE THIS PLANET (MOVIE)

Richard

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ENVIRONMENTAL RESEARCH & TECHNOLOGY, INC.
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DR. GEORGE M. HIDY
Vice President &
Chief Scientist

DEV/078/84

Official Committee File

April 27, 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
APR 30 1984
WASHINGTON, D.C. 20510

Honorable James A. McClure
Chairman
Committee on Energy and Natural Resources
U. S. Senate
Washington, D. C. 20510

Dear Mr. McClure:

I am pleased to respond to your request dated April 16 to provide certain comments on the implementation of the Acid Precipitation Act of 1980.

Attached are thirty (30) copies of my written statement. I regret that I cannot join you for the committee discussions on Monday.

Should you have any questions, please give me a call.

Yours sincerely,

George Hidy

George M. Hidy
Vice President
and Chief Scientist

GMH/daw

Attachments (30)

CONCORD, MA · FORT COLLINS, CO · HOUSTON, TX · LOMBARD, IL · NEWBURY PARK, CA · PITTSBURGH, PA · WASHINGTON, DC

Dr. George M. Hidy
Vice President and Chief
Scientist
Environmental Research and
Technology, Inc.

STATEMENT
FOR THE RECORD OF
THE COMMITTEE ON ENERGY AND NATURAL RESOURCES
U.S. SENATE

Ladies and Gentltmen:

I have been asked by your staff to send this written statement of my opinions about several issues relating to acid deposition and the National Acid Precipitation Assessment Program (NAPAP). My qualifications to provide you with this statement include: (a) the experience of twenty-five years of research in air pollution chemistry, with recent emphasis on source-receptor relationships for acid deposition; (b) membership on the EPA Science Adivsory Board, (c) membership of the National Academy of Science's Environmental Studies Board, the Tri-Academy Committee on Acid Precipitation and the Committee on Atmospheric Transport and Chemical Transformation in Acid Precipitation; (d) membership of the Deutch Committee to review NAPAP program; and (e) Peer Reviewer for the NAPAP Atmospheric research program and its Canadian counterpart.

The issues and comments are listed as follows:

A. Causes and Effects of Acid Precipitation

The causes of acid deposition are well understood in a broad sense, though specific pathways between source emissions and receptor conditions are only coarsely characterized in North America. A number of effects of acid deposition have been hypothesized. Perhaps best documented is the corrosion and deterioration of materials. The effects on aquatic and terrestrial ecosystems involve complex chemical interactions with surface waters, soil media and biota. These are poorly understood at present and probably will remain so for sometime to come. The historical effects on surface waters and forests are ambiguous and poorly documented after close examination of available data. The effects on agricultural crops and humans appear to be minimal.

B. Adequacy of the National Plan for Advancing Knowledge

The NAPAP should advance our general knowledge about the origins and effects of acid deposition on a broad front. However, the program lacks the focus and resources to provide for the assessment of issues for regulatory policy development given the time schedule originally specified.

C. Consensus on Solutions to Problems

There appears to be a lack of consensus on the nature, extent and significance of adverse effects of acid deposition. Recently, for example, the NAPAP investigators met and collectively retreated from an earlier position about the causes of apparent damage due to acid deposition. Changes in surface waters and forests have been observed, for example, but the causes are not definitely associated with acid deposition.

If the perceived effects warrant a regulatory solution, there appears to be reasonable consensus that sulfur and nitrogen oxide emission should be implemented. The geographic selectivity (extent) and the timing for such reductions remain poorly resolved.

D. Adequacy of Knowledge for Regulatory Decisions

When asked this question two years ago, I stated that the scientific knowledge at that time was adequate to consider emission regulation, but the benefits of control could not be estimated. Now I am less convinced that the scientific information is adequate. The recent research results have not clarified the questions about effects and the resources-at-risk. Instead, the scientific issues have become more clouded, showing previously unknown complexity in chemical interactions.

E. Potential for Economic, Social and Environmental Consequences of Regulatory Action

We are now faced with a major dilemma in taking action to reduce acid deposition. There are potential effects that may in time create significant economic less in material damage, deforestation and accelerated acidification of surface water. However, current projections of emission control costs are staggeringly large with poorly defined social benefit. The issue of "who pays" for control remains unresolved. There nevertheless appears to be a broad rationale for emission control embedded in a national philosophy. A coal based electrical energy production is desirable for the foreseeable future. Given the suspected environmental stress of emissions from coal combustion, it may be prudent to make a national commitment to clean coal use over the next fifty years. If so, a long term policy planned emission reduction through promotion of advanced combustion and control technology makes sense. Then a rationale can be promoted for a national "surtax" to provide for public underwriting of a long-term, broad based emission control and plant modernization program. Protection rationalized solely on mitigation of perceived effects of acid deposition is unwarranted, in my opinion, economically, socially, or environmentally.

In addition to the issues raised in the above questions, I was asked to address the consequences of present legislative and regulatory proposals for reducing sulfur oxide emissions from fossil fueled energy sources. The present proposals include several under consideration in the Senate and the House of Representatives, and the proposal to the Administration last fall by Mr. Ruckelshaus of EPA. In one form or another, these proposals all seek to implement early, brute force controls on major coal burning (power) plant east of the Mississippi River. There are some differences in geographic specificity and level of control, but nevertheless the targets are major point sources representing the backbone of America's electrical energy production. In undertaking regulation, we must bear in mind that the influence of proposed reductions all contribute little to reducing a cumulative deposition over the next 25 years. Thus, 50% reductions planned or proposed over the next decade appear impressive, but do not reduce the cumulative, total acid deposition dramatically. Thus, there is a question of the extent in "real" long-term benefits from massive across-the-board control programs proposed even if the effects results were definitive.

Implementation of any of the control proposals will constrain the use of eastern coals, and favor western low sulfur coals. Available control measures for existing plants use scrubbers or fuel washing. These undoubtedly would apply, but would substantially increase the cost of electricity and would follow with increases in industrial products as well as domestic energy supplies.

As a short term expediency, industry may favor the use of natural gas for new plants, and shift away from coal. This would be unfortunate since the application of new technology for clean combustion of coal needs to be expedited and demonstrated. Further, our natural gas supplies remain a valuable, quality fuel and must be carefully managed.

If western coal resources are tapped for eastern use, a major strain will be placed on the present rail and barge transportation system. Further, a deepened labor disruption in eastern coal producing states can be expected.

Given these prospects, the proposed legislation for control of SO_x emissions seems a bitter pill to swallow with very uncertain benefits for a highly stressed economic system. If progress is to be made, and acid deposition is the malady to be treated, the "Ruckelshaus experiment" appears to be the least painful and perhaps most instructive of potential benefits for your consideration.

Thank you for the opportunity to submit these remarks for the record.

ASSESSING THE EFFECTS OF ACID RAIN ON FORESTS OF THE EASTERN U.S.

Testimony to the United States Senate
Committee on Energy and Natural Resources

Arthur H. Johnson
Associate Professor (Soils)
University of Pennsylvania, Philadelphia, PA 19104
April 30, 1984

Determining the effects that deposition of acidic substances has had or will have on forests requires an understanding of the direct effects acidic substances have on plants, and the indirect effects which might alter soils or soil-mediated processes. There has been a substantial number of experimental and theoretical research projects which have given us mixed signals about what acid deposition can do. Results of the experimental work indicate that simulated acid rain can have negative effects, positive effects, or no effect on the growth, germination, or resistance to disease of forest trees, but we do not have the appropriate nutritional or physiological information to understand why the effects were observed. We cannot, at present, confidently assess what is actually happening or what might happen in our forests based on the experimental results because we lack detailed process-level information, because the experimental acid applications are not uniform in producing benefit or harm, and because the experimental conditions are simple compared to the complex of factors which controls the growth, reproduction and health of trees in the forest.

We have some interesting results from empirical studies of trends in tree growth and mortality and statistical analysis of the relationship of the growth rate patterns to natural phenomena and to patterns of pollutant emissions and deposition. The results of these types of investigations have shown that in a large number of cases, the growth of forest trees has been substantially less than expected during the past 15 to 25 years, and that in a few cases, mortality has been substantially greater than expected. In relatively few cases has growth been greater than expected. The generalities cited above are the result of data which has been gathered by a number of scientists from measurements of tens of thousands of trees in thousands of plots in 14 states east of the Missisippi. The unexplained reductions in growth and/or increases in mortality have been observed in six or seven coniferous species in Maine, New Hampshire, Vermont, New York, New Jersey, Virginia, Tennessee, North Carolina, South Carolina, Georgia, and Alabama. I hasten to add that the factors which are involved in these phenomena are presently not known; they may be different in different areas, and the role, if any, of acid rain has not been identified.

The findings in North America have been derived from studies of tree rings carried out by many investigators in many locations, and from repeated measurements of tree diameters carried out largely by the U.S. Forest Service. Tree ring studies conducted in central and northern Europe have shown the same anomalous patterns in diameter growth rates in recent decades, followed by alarming incidences of decline and mortality in several species.

Because the changes are substantial (growth rates of 10-40 percent less than expected) and cover broad geographic areas of aesthetically and commercially valuable forests, identification of the cause or causes of these unexpected trends in growth and mortality should be a high priority. Because these changes have been identified in areas receiving moderate to heavy rates of acid deposition, and because the changes occurred during a period when acid deposition has intensified and spread, considerable speculation exists as to how acid rain might be involved. The current state of our understanding based on sound scientific investigations is as follows:

1. **Substantial and easily visible changes in growth have been identified in tree ring studies of some conifers across their ranges in the eastern U.S.** This phenomenon is well documented in 8 states and three species, pitch pine, shortleaf pine and red spruce. Preliminary indications are that this phenomenon is apparent in other species of conifers. The change to abnormally small yearly growth increments is generally rapid and is observed in a substantial proportion of the populations. This change to reduced growth apparently signals the onset of stress, and it occurs after 1955, but in different years in different trees. Trees in all age classes are affected. We have been unable to explain this rather synchronized, regional and long-lasting effect solely on the basis of natural growth-controlling factors such as weather patterns, drought, temperature anomalies, competition, disease, insects, or catastrophic events such as ice storms, hurricanes, etc. It is reasonable to suspect that airborne pollutants alone or in combination with natural stresses could be involved.

2.**Forest Survey data from the Piedmont region of the southeastern U.S. show very clearly unexpected, reduced growth of economically important conifers in the 1970's compared to the 1960's.** These findings are new, and the meaning of this reduction in growth and the factors responsible are not known. The two most important timber species in the South, loblolly and slash pine show inexplicably low growth rates across all of the Piedmont in Alabama, Georgia and South Carolina.

3. **Unexplained, massive mortality has occurred in red spruce in high elevation forests of the Appalachians.** This type of mortality has been documented in North Carolina, New York, Vermont, and New Hampshire, and will likely be clearly identified in other areas soon. Whether or not anomalous mortality has occurred in other species of the high elevation forests is uncertain at present.

4. **The high-elevation forests of the eastern U.S. are subject to extremely high rates of acid deposition, and other airborne substances compared to low elevation forests of the East.** The high rates of input result from high rainfall amounts and prolonged, frequent contact with clouds which cap the mountains. The substances for which we have adequate documentation include sulfuric acid, acidifying nitrogen compounds and heavy metals, particularly lead. Thus by comparison to most of the forests in the east, the remote mountain peaks of the Appalachians are highly polluted environments.

4. **Determining whether or not the mortality in spruce and the anomalous growth trends are related to acid deposition or other pollutants is complicated by several factors.** At this time, no symptoms attributable to a specific pollutant or to a specific type of failure in the plants have been identified. We do not know how resistant the plants or the ecosystems are to ambient doses of the individual pollutants, or combinations of pollutants, or how pollutant and natural stresses interact. We are currently unable to conclusively rule out natural stress as a primary cause in most of the cases.

5. **There is currently no consensus among the scientific community about the involvement of acid deposition in the anomalous growth and mortality patterns observed here and in central Europe.** I stress that there is no clear evidence that acid rain is involved, and there is no clear evidence that acid rain is not involved. It is an open question. I suggest that any political decisions made with our current level of understanding should take into account that recent trends in growth and mortality are, in many cases unfavorable, that these trends have been identified in areas receiving a mix of pollutants including acid rain, and that the sum of the evidence suggests that airborne pollutants are reasonable possiblilities as major contributors. Convincing evidence regarding the involvement of sulfur emissions could emerge from ongoing and planned research, but that evidence is not presently in hand.

The Connecticut Agricultural Experiment Station

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April 25, 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
APR 27 1984

Senator James A. McClure
United States Senate
Committee on Energy and Natural Resources
Washington, D.C. 20510

Dear Senator McClure:

Thank you for your letter of April 16, 1984 inviting me to file a statement in connection with the April 30, 1984 oversight hearing on acid rain being held by your Committee on Energy and Natural Resources.

You asked specifically about the causes and effects of acid rain. My colleague Dr. Frink and I are pleased to submit an article entitled "Acid rain on acid soil: a new perspective", published in SCIENCE magazine, Vol. 221:520-525 (1983). We believe that this represents a substantial advance in the state of scientific knowledge since your committee's hearing on August 19, 1982. The summary of the article states:

> "Acid rain is widely believed to be responsible for acidifying soil and water in areas of North America and northern Europe. However, factors commonly considered to make landscapes susceptible to acidification by acid rain are the same factors long known to strongly acidify soils through the natural processes of soil formation. Recovery from extreme and widespread careless land use has also occurred in regions undergoing acidification. There is evidence that acidification by acid rain is superimposed on long-term acidification induced by changes in land use and consequent vegetative succession. Thus, the interactions of acid rain, acid soil, and vegetation need to be carefully examined on a watershed basis in assessing benefits expected from proposed reductions in emissions of oxides of sulfur and nitrogen."

Senator McClure
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April 25, 1984

I also wish to submit the Report of the Connecticut Acid Rain Task Force, Connecticut Agricultural Experiment Station Bulletin 809 (1983). The Task Force was co-chaired by Dr. Frink and the recommendations found on page 14 represent a consensus of opinion by the Task Force concerning future needs.

In conclusion, I urge that natural processes of acidification be more carefully considered in assessing benefits expected from proposed reductions in emissions of oxides of sulfur and nitrogen.

Sincerely yours,

Edward C. Krug

Edward C. Krug
Assistant Soil Scientist

cc: Director Waggoner

ECK/cas

Reprint Series
5 August 1983, Volume 221, pp. 520-525

SCIENCE

Acid Rain on Acid Soil: A New Perspective

Edward C. Krug and Charles R. Frink

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Acid Rain on Acid Soil: A New Perspective

Edward C. Krug and Charles R. Frink

Summary. Acid rain is widely believed to be responsible for acidifying soil and water in areas of North America and northern Europe. However, factors commonly considered to make landscapes susceptible to acidification by acid rain are the same factors long known to strongly acidify soils through the natural processes of soil formation. Recovery from extreme and widespread careless land use has also occurred in regions undergoing acidification. There is evidence that acidification by acid rain is superimposed on long-term acidification induced by changes in land use and consequent vegetative succession. Thus, the interactions of acid rain, acid soil, and vegetation need to be carefully examined on a watershed basis in assessing benefits expected from proposed reductions in emissions of oxides of sulfur and nitrogen.

Acid rain is widely considered one of our most serious environmental problems. In landscapes where hydrology and geochemistry do not allow complete neutralization of acid runoff, acid rain is thought to be acidifying lakes and streams, as well as mobilizing aluminum and other metals toxic to fish and plants. Nutrients are also thought to be depleted by acid rain, raising concern about large areas of productive forests located on soils that are strongly acid and low in nutrients. A gradual acidification and sterilization of our soil and water, particularly in parts of the Adirondacks, northern New England, southeastern Canada, and southern Scandinavia, is predicted.

From its inception, however, soil formation in humid temperature climates is an acidifying process, mediated by the classic factors of geology, climate, biology, topography, and time. Indeed, the factors thought to make landscapes sensitive to acid rain are those that develop some of the most acid soils in the world. The results of natural soil formation are those attributed to acid rain: leaching of nutrients, release of aluminum, and acidification of soil and water.

Landscapes have usually been assumed to act merely as net sinks for acid rain (*1*), but generation of acidity in soils has recently been recognized as an additional source. This is evident in reports of the Norwegian project on "Acid Precipitation—Effects on Forests and Fish" (the SNSF project), for example (*2–4*). However, acid rain is still considered principally responsible for regional acidification (*2–4*), because the increased flux of SO_4^{2-} in rain is thought to result in equivalent leaching of hydrogen ions and other cations. We believe that this assessment needs reexamination. Large amounts of humic acids are present in forested landscapes thought to be particularly sensitive to acid rain. The solubility of these humic acids is controlled by *p*H, and hence they effectively regulate both acidity and anion flux.

In this article we define acidity in relation to rain and soil, describe how soil formation can acidify soil and water as well as leach nutrients and aluminum, show how humic acids buffer soils, and finally discuss the impact of changing land use and consequent vegetational succession. We wish to show that natural soil formation is often more important than acid rain in determining the acidity of lakes and streams.

Acidity of Rain and Soil

Rain in equilibrium with carbon dioxide in the air has a *p*H of about 5.6. Rain at *p*H 4.6 is often said to be ten times more acidic, but this neglects the acidity of undissociated carbonic acid (H_2CO_3) normally present in rain. The strong acid necessary to reduce the *p*H of rain from 5.6 to 4.6 actually represents a twofold rather than a tenfold increase in total acidity (*5*).

The acidity of rain has also been expressed in terms of the amount of limestone, $CaCO_3$, that can be neutralized or leached from the soil (*6*), but the amounts that can be dissolved by rain at *p*H 5.6 are often ignored. An annual rainfall of 1 meter per hectare at *p*H 5.6 can dissolve 400 to 500 kilograms of $CaCO_3$ per hectare, depending on the values of the thermodynamic constants used (*5*). Rain at *p*H 4.6 can dissolve an additional 10 to 12 kg/ha, and rain strongly acidified to *p*H 4 can dissolve an additional 50 kg/ha or about 1 kiloequivalent per hectare. For comparison, managed agricultural soils in the northeastern United States may require limestone additions of 50 to 100 keq/ha per annum.

Measurements of acid in soil are somewhat analogous to measurements of acid in rain. With clay minerals and organic macromolecules acting as immobile anion phases, soils resemble weak acids, making a thermodynamic interpretation of soil *p*H uncertain. However, certain principles apply: increasing concentrations of neutral salt decrease the measured *p*H, whereas increasing dilution with water increases *p*H. This salt effect is significant in measuring acidification of runoff.

The exchange acidity of soil is the analog of the total acidity of rain and is defined in terms of hydrogen ions readily exchanged by neutral salts. Acid humus typically has an exchange acidity of about 1 eq/kg, which is about 10,000 times greater than its acidity expressed as *p*H. In mineral soils, much exchange acidity is produced by hydrolysis of ionic aluminum. Hence, at *p*H values that are typical of strongly acid soils, ion exchange sites on minerals are occupied primarily by ionic aluminum and some additional aluminum is complexed by organic matter, giving a total exchange acidity on the order of 1000 keq/ha.

Soil Formation

The more mature a soil is the more it differs from its parent material, although the degree of difference is strongly influenced by geology. In humid temperate climates soils are more acid than their parent materials; water percolating through freshly ground granite is alkaline (*p*H 8 to 9), but soils developed from granite are acid. There is sufficient acidification that mature soils developed even on limestone or marble can be acid (*7*).

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Although chemical oxidation of reduced elements in parent materials produces acidity, it cannot account for the extremely acid podzols and related peats found on granite-like rocks. Acidification of these soils is biological (*8*); hence, the soils are most acid at the surface, where most decomposition and leaching occurs.

The major sources and sinks of soil acidity are illustrated in Fig. 1. Initially, weathering of freshly exposed siliceous bedrock is rapid and bases such as calcium, magnesium, potassium, and sodium are leached (pathway 3d in Fig. 1). Acid is generated by the biological oxidation of carbon, nitrogen, and sulfur, much as acid rain is created by the burning of fossil fuels. Because the partial pressure of CO_2 in soils can be 100 times that in the air, potential weathering rates by H_2CO_3 are immense, although seldom achieved in nature. Reaction and removal of hydrogen ions favor continued dissociation to H^+ and HCO_3^- (pathway 2c). With time, rates of acid neutralization, weathering, and cation denudation decrease and acids accumulate. Little H_2CO_3 is consumed by mineral weathering; most of it is lost as CO_2 and H_2O (pathway 2c). This is reflected by the low bicarbonate alkalinity of runoff from watersheds with strongly acid soils.

A layer of humus eventually forms which often lies over bleached mineral soil. Earthworms and other organisms that mix litter with mineral soil are now absent, and microbial populations have changed. Production of simple organic acids is slight, but production of partially oxidized humic acids of high molecular weight is favored (*9*). These humic acids more strongly acidify their environment than the final oxidation products of CO_2 and H_2O. The increased acidity decreases the solubility of humic acids (*10*), and enhances their accumulation. The rate of mineral weathering is now exceedingly low, most organic acids are lost as CO_2 and H_2O, and the upper mineral soil is a highly weathered siliceous residue resistant to acid weathering. This process is known as podzolization, and soils with distinctive bleached horizons are known as podzols.

It is often thought that acid humus accumulates because organic matter decomposes slowly. This is clearly true where thick peat develops under sparse vegetation. It is not true for the productive forests on podzolized acid soils in the Northeast, southeastern Canada, and Scandinavia (*11*), where concern about acid rain is greatest.

Formation of mature podzol soils from freshly exposed materials is measured in thousands of years, because the capacity of the parent material to neutralize acid is great relative to rates of weathering. For example, the potential for neutralization of acids by the parent material at Hubbard Brook in New Hampshire is nearly 21,000 times greater than the yearly inputs of acid rain and 11,000 times greater than the estimated rate of mineral weathering (pathways 3a to 3d in Fig. 1) (*12*). In addition, the aluminum oxides in the parent material neutralize acid in water (pathway 3c) when the *p*H is below 5 and serve as an enormous sink against acidification (*13*).

Although some preferential flow occurs in soils, so that not all ion exchange sites can react equally with leachate, the time scale of weathering allows distinctive soil horizons to develop parallel to the earth's surface rather than surrounding vertical channels of preferential flow. Given the rate of soil formation, or even the 100 or more years said to be necessary for significant leaching of cations by acid rain (*14*), strong acidification of mineral soil is generally restricted to the upper soil profile. In addition, the earth's surface is not stable: erosion, tree throw, frost heaving, and soil creep constantly expose new and less weathered mineral material. Although the amounts of soil moved are small, the corresponding resistance to acidification is large. Only where weathering can keep pace with disturbance do we see mature, albeit heterogeneous, soil development.

Acidification of Soil and Water

Because cation exchange reactions are rapid, hydrogen ions in acid rain could rapidly acidify soil by depleting exchangeable base nutrients. If increases in H^+ in acid rain (ΔH) leached nutrient cations (ΔM) from soils on a charge-equivalent basis (that is, $\Delta M/\Delta H = 1$), strongly acid soils would be highly susceptible to acidification because of their low nutrient content. However, the ability of hydrogen ions to remove nutrient cations from soils more acid than *p*H 5 is low; that is, $\Delta M/\Delta H \ll 1$ at the mean *p*H of present-day acid rain (*15*). Conversely, base nutrient cations are efficiently retained. Data on acid soils and acid rain in areas of concern around the world show that, on average, the proportion of bases to acid in the rain is usually equal to or greater than that in the strongly acid forest soils on which the rain falls (*15–17*).

Artificial leaching experiments, some

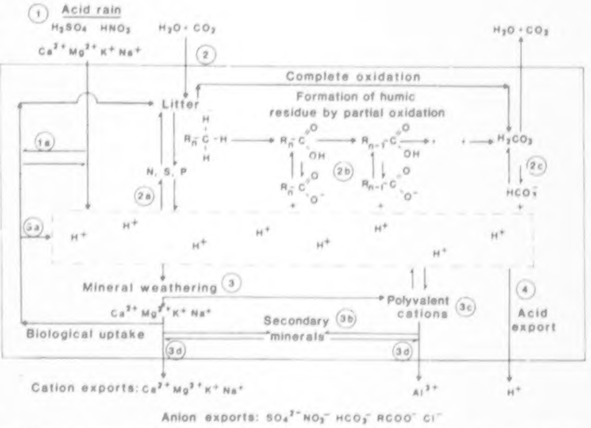

Fig. 1. Major sources and sinks of acidity in soil. Acid rain (1) is a source of acidity, but its composition may be altered before reaching the soil (1a). Although biological processes (2) are net sources of acidity, this obscures the fact that they serve as a substantial sink in acid soils through the production of weak organic acids (2b), which are ultimately converted to CO_2 and H_2O (2c). Mineral acids (2a) can be cycled rather tightly, with some sulfur and nitrogen lost to the atmosphere and some sulfur and phosphorus converted to solid phases. Weathering of minerals (3) generally consumes acid in excess of cation export (3d), as secondary minerals (3b) and hydrolysis products of aluminum, iron, and manganese (3c) accumulate in soil. Aggrading vegetation results in net cation uptake (3a) and can contribute to acidification. Rain which is less acid than the soil solution can also be acidified by hydrolysis (3c). Cation (3d) and acid (4) export is charge-balanced principally by anions shown at the bottom.

of which have lasted up to 5 years, verify that acid rain at *p*H 4 or higher is inefficient in replacing base cations from podzols and related acid soils (*2–4, 18*). As soil *p*H increases above 5, base cations are replaced more efficiently. Thus, the less acid soils with low cation exchange capacity developed on coarse siliceous materials are actually more susceptible to acidification (*15*). Little research has been conducted on the impact of acid rain on such soils (*19*).

Bicarbonate alkalinity is the principal measure of the ability of lakes to resist acidification. In highly siliceous watersheds with acid soils where rates of mineral weathering by H_2CO_3 are low, inputs of HCO_3^- per unit drainage area are also low. Lakes in such watersheds with small ratios of drainage area to lake area could be acidified by acid rain falling directly on them. Little change in *p*H will occur until 80 to 90 percent of the bicarbonate has been neutralized (*20*). One lake in Canada that occupies about 40 percent of an entire watershed has apparently been directly acidified by acid rain (*21*). However, this direct acidification is usually considered a minor factor relative to acid runoff (*2–4, 20, 22*).

Alpine-like lakes and streams in granitic terrain are believed to be especially vulnerable, particularly where there is little mineral soil and permeable geologic material to neutralize runoff from acid rain. Also, the relatively steep and short slopes of these landscapes minimize infiltration and time of contact with neutralizing minerals. The granitic shield and similar areas of eastern North America and northern Europe also have large proportions of extremely acid peats with only small amounts of weatherable minerals (*1, 20, 23–26*). Because these peats often border lakes and streams, they can exert a disproportionately large influence on water chemistry (*25, 26*). For example, acid peats cover 24 percent of a watershed in southernmost Norway, and 62 percent of the drainage flows through them (*26*).

The factors thought to make these landscapes sensitive to acid rain also limit neutralization of runoff acidified by acid soil. The thin and rocky soils that develop on these areas naturally produce such thick humus that they are often classified as organic soils (*17, 24, 27–31*), and they have a lower *p*H than the thicker soils downslope (*27, 31–33*). This topographic gradient in soil chemistry and other properties, where the upland soils are "leaky" and act as A horizons and the lower-lying sites act as B horizons, is known as a geochemical soil catena (*34*). Thus, a gradient in stream acidity paralleling a soil catena in mountainous areas should not be surprising, although it is not always evident. Such gradients have been observed at Hubbard Brook and other mountainous watersheds in the northeastern United States, but the acidification has been attributed entirely to acid rain (*35, 36*).

The interim report of the SNSF project attributed acid runoff solely to acid rain (*1*). This evoked criticism from other Scandinavian scientists, who noted that the amounts of acid in soils are enormous relative to that in rain and that runoff from acid soils will be acid regardless of the *p*H of rain (*37, 38*). They suggested that in such watersheds, runoff from heavy rains and rapid snowmelts is acidified because a greater proportion is in contact with the most acid surface soil horizons. Thus, hydrologic factors can make rapid runoff significantly more acid than runoff from gentler rains or slower snowmelts, which percolate to a greater depth and more slowly through less acid subsoil and geologic materials. In short, the effects of acid rain were said to be confused with those of acid soil (*37, 38*).

A later report of the SNSF project acknowledged that soils can act as both sources and sinks for acid and that the effects of acid rain were not clearly expressed even in watersheds as small as 10 ha (*39*). Accordingly, "minicatchments" ranging in size from 0.003 to 0.026 ha were established. Because of their small size, shallow soil, and large areas of exposed bedrock (46 to 74 percent), these catchments represent a worst case where the effects of acid rain should be most evident (*39*).

On average, runoff in the minicatchments was twice as acid as the acid rain, and the *p*H of the runoff was correlated with soil *p*H. Only for the heaviest rains in the smaller basins was the *p*H of rain found to measurably affect the *p*H of runoff (*39*). There was essentially no difference in acidity between the snowmelt from a snowpack at *p*H 4.3 and that from a snowpack neutralized to about *p*H 7 (*40*). Artificial rain at *p*H 3.85 acidified runoff by 0.2 to 0.4 *p*H unit, but it was concluded that further studies were needed to determine whether such acid rain can measurably acidify runoff in larger watersheds (*41*).

Although it has been demonstrated that acid soils can acidify runoff, it is still contended that acid rain is the major factor in the acidification of leachate and runoff. We believe that this is due to a number of misconceptions. One of them concerns anion leaching. As we noted earlier, hydrogen ions in acid rain at *p*H 4 or greater are inefficient in exchanging bases and thereby in acidifying strongly acid soils. Accordingly, most of the hydrogen ions in rain are thought to remain in solution and move through the soil accompanied by sulfate as the principal anion (*2–4, 20, 22, 42*). Sulfur in rain generally exceeds the nutrient requirements of forests, and humic materials coat aluminum and iron oxides that might otherwise immobilize sulfate by anion fixation (*1, 2–4, 20, 42, 43*). Thus, most of the H_2SO_4 falling on these soils is thought to move through them, causing increased cation leaching proportional to the increased flux of SO_4^{2-}. Similarly, acid peats are considered to offer little resistance to acidification of runoff by acid rain (*1, 2–4, 20, 26*).

However, the anion leaching theory has a major flaw. Watersheds considered to be most sensitive to acid rain have soils that are strongly acid and rich in humus, and their chemistry is not one of simple ion exchange. Humic materials act as weak acids; they dissolve in water and color and acidify it. The solubility of humic materials is a function of *p*H: the more acid the water, the less is dissolved (*10*). Sulfate apparently does not react strongly with humic materials, but the added H^+ in acid rain hinders their dissociation and decreases their solubility (*10*). The response is analogous to that of an inorganic system containing an excess of a sparingly soluble solid phase. Thus, additions of H_2SO_4 in rain should increase the flux of SO_4^{2-} and decrease the flux of organic anions with little or no measurable change in *p*H (*44*). Organic acids that accumulate are fated to be oxidized to CO_2 and H_2O.

Such a buffering mechanism helps explain why acid rain does not increase cation leaching in strongly acid soils at rates equivalent to deposition (*18, 45*). Rates of cation export from watersheds in the northeastern United States, Canada, and Norway which are thought to be sensitive to acid rain are remarkably low (*1, 35, 46–49*). Investigators at Hubbard Brook found it perplexing that the rate of cation export from the watershed was unusually low and apparently not enhanced by acid rain (*49*). Johnson (*35*) reported that "geologically, no excessive chemical weathering activity [as measured by cation export from watersheds] can be attributed to acid rain over the northeastern United States."

Other researchers state that the strong acids in acid rain result in equivalent leaching of cations (*1, 46–48*), but this conclusion is not supported by their own data. For example, rates of loss of cations in rivers in Canada are lowest where inputs of acid rain are highest (*47*). If the assumption of equivalent leaching were strictly applied to Norwegian data there should be no net loss of cations without acid rain, because net losses of cations are equivalent to inputs of acid in acid rain (*1*, *48*).

The organic acid buffering mechanism also offers an alternative explanation of the observation that humic-colored lakes in Scandinavia are becoming clearer, an effect previously attributed to precipitation of humic acid by iron and aluminum dissolved by acid rain (*50*).

Leaching of Aluminum

The presence of aluminum ions in solution in soil and water at *p*H 5 or less has been considered evidence of dissolution of aluminum by acid rain (*1*, *43*, *51*). Even though it has long been known that large amounts of soluble aluminum are present in acid soils, the discovery of leaching of soil aluminum by acid rain (*43*) has been described as a principal and historic contribution (*52*). The discovery was based on the observation that there is considerably less aluminum mobilization in "pristine" sites in New Mexico and Washington than in "polluted" sites at Mount Moosilauke in New Hampshire. This is not surprising, however, since the soils in New Mexico and Washington are naturally less acid than those in New Hampshire (*53*).

There is a further misconception that aluminum leached from the A horizon of podzols is normally immobilized in the B horizon, and hence that aluminum in leachate which has moved through the B horizon must have been dissolved by acid rain. Such movement of aluminum out of soils is implicit in the concept of the geochemical soil catena (*34*). Some aluminum is leached and may appear in surface waters, as shown in 1930 by Joffe and later by others (*54*, *55*). Indeed, at the sites in Washington examined by Ugolini and co-workers (*53*) one-third to one-half of the aluminum from the A horizon remains in solution in the B horizon. Aluminum does not appear in nearby spring water because it is precipitated as the water moves through fractured basic andesite bedrock. In New Hampshire, on the other hand, the water moves rapidly over solid bedrock, and hence aluminum appears in adjacent spring water.

The belief that aluminum ions in water result from acid rain is supported by the idea that all aluminum leached from organic-rich soils is complexed by organic anions. In humic-rich soils at *p*H 4.5 to 5, humic materials do complex most of the aluminum, as shown 50 years ago (*56*). However, aluminum complexation decreases dramatically as the *p*H decreases below about 4.5. Likewise, the solubility and mobility of complexed aluminum decrease as acidity increases (*10*, *57*). Accordingly, ionized aluminum should be expected in water draining from organic-rich soils at *p*H 4 or less. This may also help explain why more aluminum is leached from the upper soil horizons at the Washington sites at *p*H 4.5 to 4.7 than at the New Hampshire site at *p*H 4 (*43*, *53*).

Basic cations in rain may also promote exchange of ionized aluminum from acid soil into leachate and runoff. Indeed, the data from the snowmelt study mentioned earlier suggest that sodium in the neutralized snowpack replaced aluminum on exchange sites, which increased the concentration of aluminum in runoff for several weeks to about twice that in corresponding runoff from the snowpack with *p*H 4.3 (*40*). Acid rain may also increase the concentrations of base cations in forest throughfall. For example, about 90 percent of the hydrogen ions in acid rain at Hubbard Brook are neutralized in the northern hardwood canopy during [illegible] growing season; *p*H 4.1 rain becomes *p*H 5.0 throughfall (*58*). Although these leached nutrient cations are apparently taken up by the forest (*59*), the effects on aluminum chemistry are not known. Future studies should be carefully designed so that ion exchange by neutral salts (the salt effect) is not confused with dissolution of aluminum by acid (*60*).

Effects of Changing Land Use

Both regional acid rain and drastic changes in land use are associated with societal and technological evolution. Earlier, the exploitation of temperate forests was widespread and highly destructive. The remaining forests of western Europe all show the influence of man (*61*). The extensive heaths of Great Britain, Scandinavia, and northern Europe are the consequences of earlier and careless land use (*62*). Several thousand years of burning, grazing, and cutting caused severe erosion, which helped to create the unusually thin soils and low treelines of the uplands and low mountains of southern Norway (*2*, *38*, *63*). Many of these practices were transported to eastern North America with the arrival of the Europeans more than three centuries ago.

Fortunately, the temperate forests in Europe and North America were sufficiently resilient that they are now recovering. In New England, the volume of standing wood has increased by about 70 percent between 1952 and 1976 (*64*). Worldwide, temperate forest regrowth is so great that it may influence the global carbon cycle (*62*, *65*). Given the effects of vegetation on soil acidification, there is little doubt that recovery of landscapes from earlier disturbance can result in increasingly acid surface soil horizons and thickening and acidification of forest floors.

In the 1920's, Salisbury (*32*) demonstrated that successional change and forest recovery from previous exploitation were responsible for widespread acidification of British landscapes; the upper slopes, with their acidophilic vegetation, were shown to be undergoing the greatest acidification. Large-scale recovery of forests in New England stimulated early studies in Connecticut. Red pine planted in 1900 on abandoned corn and tobacco fields developed a forest floor with a *p*H of about 3.8 (*66*). Other plots were established in 1926 and 1927 in 20- to 40-year-old hardwood stands and have been protected from cutting and burning. Our measurements show that today hardwoods have acidified the forest floor at one site from about *p*H 5.5 to 3.9 and the underlying mineral soil from *p*H [illegible] to 4.6 (*67*). At another site there was almost complete mortality of oak from drought and defoliation. Basal area declined from 30.5 m^2/ha in 1957 to 4.6 m^2/ha in 1977. Here, we found that the *p*H of the forest floor had actually increased from 3.8 to 4.2 (*67*).

While soil properties and effects of changing land use vary from site to site and are even heterogeneous within sites, some general relations are evident. Land use and forest management studies in North America and northern Europe reveal that disturbance under conifers affects acidity and depth of humus more than similar disturbance under hardwoods (*28*, *29*, *54*, *68*, *69*). Likewise, the greater the disturbance, the greater the effect. Mixed hardwood-conifer forests are intermediate, but their response to disturbance tends to resemble that of conifers (*28*, *29*, *54*, *68*–*70*). Thus, as Salisbury (*32*) concluded, recovery from earlier disturbance will have its greatest effects on the upper slopes—that is, on strongly acid soils rich in organic matter.

In the northeastern United States, the most severe changes have occurred in the spruce-fir forests of northern New England and on the steep slopes of the Adirondacks, where acid rain is thought to be particularly harmful. By the early 1900's essentially all the spruce-fir forests had been clear-cut for pulp, except for a small fraction of the forest in the Adirondacks which was preserved (*30, 71–73*). The original spruce-fir forests were very resistant to fire (*72, 74*), but lumbering was often followed by severe fires that largely or completely destroyed the thick forest floor (*28–30, 73, 75*).

The more intense a forest fire, the greater the effects on depth and acidity of the forest floor. Organic acids are oxidized and lost to the atmosphere, leaving alkaline ash on the soil (*28, 29, 54, 68, 69*). In managed spruce forests in Scandinavia, where controlled burning reduced the depth of humus by only 1 cm, the *p*H of the remaining 4 cm of humus rose 2 to 3 units. After 50 years the original depth of humus was restored, as was the original *p*H of 4. The *p*H of the upper mineral soil was still elevated by about 0.2 *p*H unit (*69, 76*).

The depth of the forest floor under undisturbed stands of spruce and fir on the upper slopes of the Adirondack, White, and Laurentian mountains commonly exceeds 30 cm and the *p*H is less than 3.5 (*27–31*). Diebold (*28*) showed that in the Adirondacks, fire in spruce-fir slope forests is more destructive to the forest floor than in other forest types (*28, 29, 68, 69, 75*). On the average, the depth of the forest floor up to 30 years after burning was reduced by 30 cm. The thinner and less acid forest floors of the lower slopes and valleys were reduced by 5 to 13 cm (*27–31*).

On the steeper slopes of the White Mountains the depth of the forest floor ranges from discontinuous to 5 to 10 cm (*77*), suggesting widespread destruction of the original forest floor. The depth of the forest floor may also be reduced in the absence of fire: in cutover but unburned Adirondack spruce forests the floor averages about 5 cm in depth (*78*).

The effect of cutting and burning on the *p*H of the forest floor on the steep slopes of the Adirondacks has apparently not been determined. In the various forest types of the lower slopes and valleys, Young [in (*68*)] showed reductions in the depth of the forest floor from both cutting and burning that were similar to those reported by Diebold (*28*). The *p*H of the forest floor averaged about 4 in undisturbed stands, but under stands that were cut or burned the average *p*H was about 5 when measured 20 to 50 years after disturbance. The *p*H of the mineral soil averaged about 0.7 unit higher under disturbed stands.

Maturation of forests also influences hydrology. As the depth of humus increases, the amount of water percolating into the subsoil may decrease (*79*). Runoff can become more acid not only because of the increasingly acid humus, but also because of the increasing proportion of near-surface runoff. Also, snowpacks last longer under older forests, making episodic flushes more likely during periods of warm weather or rainfall (*80*). The devastating effects of spring snowmelt may be more severe in part because of changes in hydrology and chemistry induced by changes in the forest.

Although the effects of forest disturbance and recovery are variable, it is apparent that recovery results in increasingly acid soil horizons and thickening organic horizons (*28, 29, 54, 68, 69*). Accordingly, water moving through such soil should also become more acid, and the proportion of ionized aluminum to organically complexed aluminum may also increase (*57*).

Thus, mountainous areas of the northeastern United States are not pristine environments that are acted on only by acid rain. These landscapes, which were disturbed in the past, are undergoing the soil formation process that produce the greatest increases in natural soil acidity.

The idea that changing land use and consequent vegetational succession are largely responsible for acidification of soil and water in southern Norway was first advanced by Rosenqvist (*38*). Forest recovery in southernmost Norway has been dramatic: the volume of standing wood increased by more than 70 percent during the period 1927–1928 to 1964–1973. Rosenqvist proposed that this large-scale recovery of forest and the reversion of land to acid heath and forest was producing large areas of increasingly acid soils. As an illustration, he showed that the exchange acidity of surface humus under a 90-year-old spruce forest on an abandoned Norwegian farm was equivalent to the strong acids in about 1000 years of rain of 1 m per year with *p*H 4.3. He proposed that these increasing amounts of increasingly acid humus and mineral soil (*81*) are acidifying runoff in watersheds where there is incomplete neutralization of acids by mineral weathering (*38, 63*).

The final report of the SNSF project acknowledges that changes in land use and consequent vegetative succession have long been known to acidify soil and will in general affect the alkalinity and *p*H of rivers and lakes (*2–4*). Nevertheless, it considers changes in land use to be a minor factor and concludes that the observed increases in sulfate in runoff and presumed equivalent increases in leaching of hydrogen, aluminum, and other cations are responsible for most of the observed increases in acidity (*2–4*).

We believe that the effects of changing land use and vegetative succession cannot be dismissed on the basis of studies performed to date. Further, the hypothesis that increased deposition of acid and sulfate is causing equivalent leaching and acidification is theoretically unsound and is not supported by direct observations. Natural processes of acidification must be more carefully considered in assessing benefits expected from proposed reductions in emissions of oxides of sulfur and nitrogen.

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ACID RAIN

Sources and Effects in Connecticut
Report of the Acid Rain Task Force

REPORT TO THE GOVERNOR AND TO THE GENERAL ASSEMBLY
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BULLETIN 809 • THE CONNECTICUT AGRICULTURAL
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ACID RAIN

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Rain in Connecticut and the Northeast is generally more acid than that found in other areas of the United States. Opinions regarding the danger posed by acid rain range from no danger at all, to perceptions of dying fish and vegetation, corroding statues, crumbling buildings, and threats to human health.

Given this background of concern, the Connecticut General Assembly created an Acid Rain Task Force with the passage of Special Act 81-44 "An Act Concerning the Study of Acid Rain." This act charged the Task Force with studying the sources and effects of acid rain in Connecticut, and specified that the Task Force should work in cooperation with The Connecticut Agricultural Experiment Station. The act also required that the Task Force submit a final report of its findings and recommendations to the Governor and to the General Assembly on or before January 1, 1983. This document is the final report of the Acid Rain Task Force.

The members of the Task Force and the organizations that they represent are listed on the facing page. In addition to examining the nature and sources of acid rain, the Task Force examined the effects of acid rain according to the following categories: effects on soil and water, effects on fish, effects on vegetation, effects on structures, and effects on human health. Speakers addressed the Task Force on these various topics and they are listed in Attachment I, as well as others providing information to the Task Force. A brief bibliography of reference materials provided by the speakers, as well as other documents examined by the members of the Task Force are shown in Attachment II. Published materials are available from the authors. Copies of other materials may be seen in the offices of the Environment Committee.

The Task Force realized that undertaking research on acid rain was beyond its charge. As with other environmental concerns, significant disagreement exists between advocates on opposing sides of the issue, with the consequence that the public is confused. Thus, the Task Force sought out informed opinion amongst knowledgeable people, relying heavily on the considerable expertise available within Connecticut's borders. Our report indicates where a consensus of opinion was reached, as well as areas that require further investigation.

NATURE OF ACID RAIN

Simply stated, acid rain is produced by reaction of moisture with oxides of carbon, sulfur and nitrogen in the atmosphere to produce a mixture of carbonic, sulfuric and nitric acids. The principal oxide of carbon is carbon dioxide, or CO_2, which is present in normal air at a relatively constant concentration of about 0.03%. Reaction of CO_2 with moisture then produces "normal" rain with pH about 5.6. Rain with a pH lower than 5.6 is considered to have been acidified.

The principal oxide of sulfur is sulfur dioxide, or SO_2, which is produced by biological oxidation of sulfur-containing compounds and by the combustion of fossil fuels. On a world-wide basis, natural production of SO_2 far exceeds man-made sources. However, in the industrialized nations, sulfur oxides generated by man often far exceed natural production of SO_2. When coal and wood were major fuels, much of the acidity produced by combustion was neutralized by smoke and fly ash. Although early studies of the acid content of rain are sparse, it is reasonable to conclude that tall smokestacks and particle precipitators converted local soot problems into regional acid rain sometime after World

War II. A portion of the sulfur compounds in air are oxidized to sulfate ($SO_4^=$) and react with other materials to form fine particulate aerosols. The most common form appears to be ammonium sulfate, with the ammonia presumably derived from volatilization from biological materials.

The oxides of nitrogen in air are complex and usually referred to as NO_x. The principal source of nitrogen oxides is high temperature combustion, where nitrogen and oxygen naturally present in the air combine to form NO_x. As with SO_2, natural emissions of NO_x on a global basis far exceed man's contributions, but automobiles and other combustion processes overwhelm these sources in industrial areas. At present, sulfur oxides in air generally exceed nitrogen oxides, but increased emissions of NO_x are expected to increase the nitric acid component in rain.

Thus, in reality acid rain is a mixture of acids dissolved in water, reactive gaseous oxides, and fine particulate sulfate and nitrate aerosols. In addition, air contains other pollutants such as ozone, hydrocarbons and heavy metals which may interact in synergistic fashion with various components in acid rain. Consequently, acid rain must be considered as only a part of the larger problem of air pollution in Connecticut. Where possible, we shall discuss the specific sources and effects of the various constituents of acid rain, as well as indicating possible interactions with other air pollutants.

SOURCES OF AIR POLLUTANTS

It is convenient to divide sources of air pollutants into two groups, local and long range. Local sources are those whose effects occur within 20-25 miles, while long range pollutants persist for 50 miles or more. Table 1 from Yocum (1981) describes some of the characteristics of long range and local air pollutants and reveals the importance of specifying the particular pollutant of concern. For example, if damage is caused largely by gaseous SO_2, local sources are likely to be relatively more important. Conversely, ozone damage is often produced from more distant sources except under particular meterological conditions. Acid rain itself can arise from both local and long range sources.

Although New England lies generally downwind from sources of air pollutants to the west, prompting Bormann (1981) to label us "the garbage can of the United States," it is difficult to determine the relative amounts of any particular pollutant transported into Connecticut in comparison with the amounts generated within our borders. The Connecticut Department of Environmental Protection has studied the transport of ozone, sulfur dioxide, nitrogen dioxide, and total suspended particulates in some detail and their findings are discussed below.

Sources of Ozone

Ozone is produced by the reaction of sunlight with hydrocarbons and NO_x precursors in the atmosphere. Analysis of the June 10, 1974 "smog" episode in Connecticut by Rubino, Bruckman and Magyar (1976) showed that peak ozone levels occurring in Connecticut in late afternoon of that day were probably transported into Connecticut with the prevailing southwesterly wind. Continued monitoring of ozone levels in Connecticut has shown high concentrations in summer months (Connecticut Air Quality Summary, 1979). It has been estimated that transport of ozone from the New York-northern New Jersey urban complex can account for up to 70% of the concentrations measured in Connecticut on certain days in the summer (Bruckman, 1982). However, a report by the Connecticut Academy of Science and Engineering (CASE, 1979) points out that appreciable amounts of ozone may be transported into New York City from outside its borders. While the Connecticut Academy of Science and Engineering is presently re-examining the issue, their 1979 report indicated that reliable estimates of the contributions of pollutants from the New York-New Jersey area could not be made. Thus, although ozone levels in Connecticut are among the highest in the country, the precise source areas cannot be specified at present. The long range nature of ozone transport (Table 1), however, suggests that additional source areas exist outside of the immediate New York-New Jersey metropolitan area. This is particularly important in devising control strategies, since there have been significant decreases in amounts of most other air pollutants in Connecticut during the past seven years, with ozone remaining high (Connecticut Air Quality Summary, 1979; CASE, 1979).

Sources of Sulfur Dioxide

Sulfur dioxide is produced largely by combustion of fossil fuel and has a relatively short residence time as a gaseous pollutant in the air (Table 1). Emissions of sulfur dioxide east of the Mississippi River are shown in Fig. 1. Measurements of sulfur dioxide concentrations in the air in Connecticut showed no episodes exceeding air quality standards in 1979 (Connecticut Air Quality Summary, 1979), confirming a gradual reduction in concentration of SO_2 during the 1970s. Unlike ozone, concentrations of SO_2 tend to be higher in the winter, presumably due to increased burning of fuel. Measurements of SO_2 concentrations during persistent SW winds indicates that 15% to 57% of "typical" daily SO_2 levels can be attributed to transport from the New York-New Jersey metropolitan area (Bruckman, 1978). On an annual average basis, SO_2 transport from the SW is estimated to contribute 1% to 11% to the observed concentration in the air in Connecticut (Bruckman, 1978). The attainment of SO_2 standards for Connecticut is attributed to restrictions on sulfur content of fuels (Connecticut Air Quality Summary, 1979). As with ozone, however, the CASE (1979) report questions whether reliable estimates of sources of SO_2 outside Connecticut can be determined from present

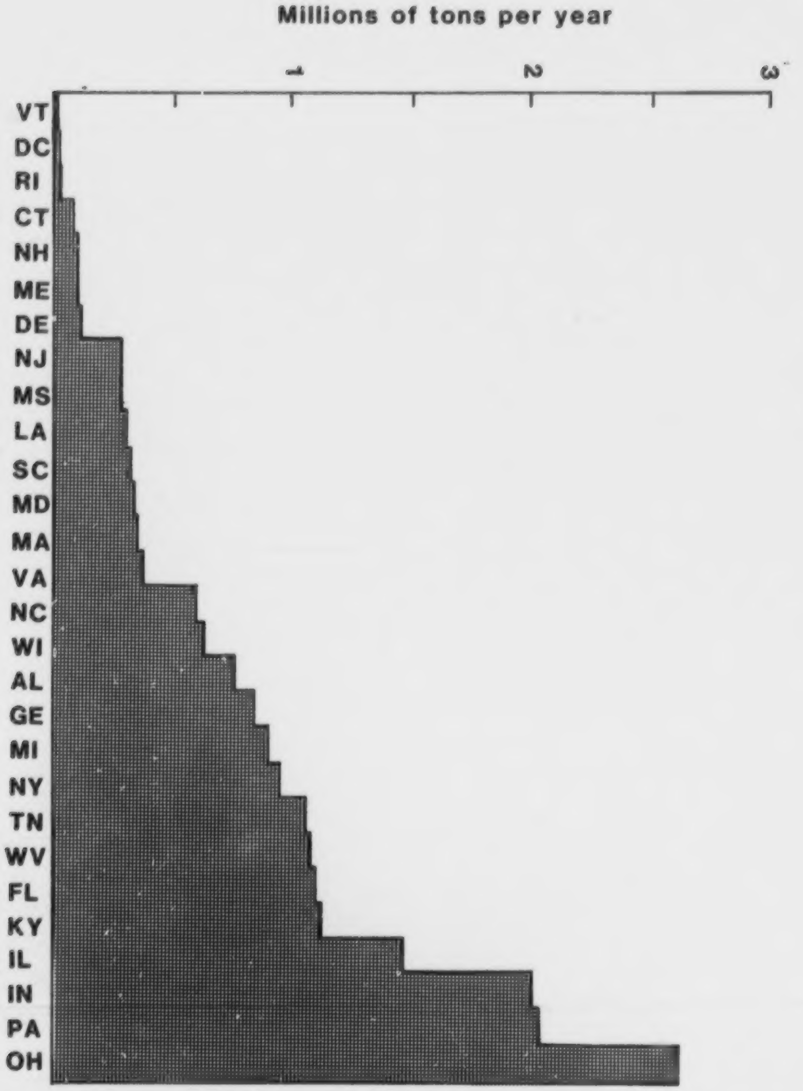

Figure 1. Estimated annual emissions of sulfur dioxide in 1980 east of the Mississippi River (Data from New England Interstate Water Pollution Control Commission).

Table 1. Characteristics of Long Range and Local Air Pollution (Yocum, 1981).

Pollutant	Long Range	Local
Ozone and Other Oxidants	Ozone and other oxidants are produced over moderate to long range transport in presence of sunlight from hydrocarbon and NO_x precursors.	Ozone and other oxidants formation are likely only under low winds and sunlight if precursors are present.
Sulfur Oxides	SO_2 tends to be oxidized to particulate sulfates.	Exists primarily as SO_2; however under stable conditions conversion to particulate sulfate can occur.
Nitrogen Oxides	Significant conversion to particulate nitrates.	Exist primarily as NO and NO_2, but under low wind speed, stable conditions and sunlight, conversions to nitrate particulates and organic nitrates are possible.
Particulate Matter	Only the smallest primary particle sizes persist. Large component of material converted from gases and vapors to particulates such as sulfates.	Exists in wide range of sizes which may be bimodal. Particles are capable of producing surface soiling.
Dry Acidic Deposition	Dry deposition of acidic particulates. (e.g., sulfates are possible.)	Dry deposition of acidic particulates is possible, especially under stable conditions, often enhanced by moist surfaces.
Acid Rain	Acidic rain mechanisms may be predominantly through droplet condensation around acidic particles.	Acidic rain mechanisms may be predominantly through rain washout of acidic particles and pollutant gases.

data. It seems important to continue to monitor SO_2 concentrations to determine effects of possible changes in allowable sulfur content of fuels in Connecticut and elsewhere.

Sources of Nitrogen Oxides

Nitrogen dioxide in the air has been measured by the Connecticut Department of Environmental Protection since 1973. During this time, concentrations of NO_2 have declined somewhat, with no episodes in 1979 exceeding air quality standards. About 60% of the NO_2 in Connecticut is estimated to come from automobiles (Connecticut Air Quality Summary, 1979). Levels of NO_2 tend to be somewhat higher in the winter months and are less dependent on wind direction than with some other pollutants.

Sources of Total Suspended Particulates

Total suspended particulates (TSP) are a complex mixture of dust, soot, aerosols, and even liquid droplets small enough to remain suspended in the air. More than half of the particulate emissions in Connecticut are attributed to fuel combustion and creation of road dust by automobiles. Identification of the sources of particulates is complicated by the fact that particle size decreases with increasing distance from the source, but particle sizes are not routinely measured. Particulates have been measured in Connecticut since 1957, but frequency of sampling and other changes in procedures make interpretation difficult. As with ozone and sulfur dioxide, increased TSP concentrations have been associated with southwesterly winds (Bruckman, 1977). In view of the characteristics of particulate matter (Table 1), it seems difficult at this time to attribute any particulate fraction to specific locations upwind from Connecticut.

Sources of Acid Rain

Given the difficulty of determining the geographic sources of specific pollutants such as ozone, sulfur dioxide or nitrogen oxides, it is clear that determining the specific sources of Connecticut's acid rain will be at least as difficult. Nevertheless, a clear association has been found between the sulfuric acid component of acid rain and emissions of sulfur dioxide. Therefore, regions where emissions of sulfur dioxide are high and that are upwind of Connecticut are undoubtedly contributing to the acidity of our rain. Table 1 suggests that mechanisms exist for transport of acid rain from both local and long range sources.

Figure 2 shows the mean annual pH of rain in the United States and Canada for the period 1979-1980 (National Research Council, 1981). Although there are relatively few data points in New England (and none in Connecticut), it appears that the region of most highly acidified rain lies considerably to the west of Connecticut. Data summarized in the Northeast Damage Report (1981) show that the concentrations of NO_3 and SO_4 in rain were also greater to the west of Connecticut during 1978-1979. The U.S. Geological Survey in cooperation with other agencies has monitored rainfall at nine stations in New York since late 1964. A recent summary of the data for 1965-1978 by Barnes et al. (1981) shows that the average sulfate concentration in rain has decreased steadily at about 2% per year. The largest decreases (up to 5% per year) were observed at Albany and at two stations on Long Island. Nitrate concentrations have increased 6% to 12% per year, while hydrogen ion concentrations increased in the western part of the state and decreased in eastern portions. These observations, coupled with a decrease in SO_2 and NO_x concentrations in the air in Connecticut, run counter to the opinion held by some that acid rain is steadily worsening in Connecticut.

Trajectory Uncertainties

One of the major issues raised by Canada and the northeastern United States is how to reduce local acid deposition, with particular emphasis on sulfur oxides and particulate sulfates. Several models to calculate the transport, dispersion, chemical reaction, and deposition of sulfates have been proposed. These models have been used to identify specific source areas, and even sources, as being responsible for specific episodes of high sulfate concentration. Bowne described the uncertainties that are inherent in trajectories calculated by using these models, which are typically 30% to 50% of the distance from the source. Thus, if the source is 300 miles away, the predicted distance of transport can have uncertainties of the order of plus or minus 150 miles. In addition, trajectories often have angular uncertainties of 20 degrees or more. Using the example above of a source located 300 miles upwind, an angular uncertainty of 20 degrees corresponds to an uncertainty of 100 miles to the right or the left of the predicted trajectory.

Similar uncertainty in the use of models was reported by Hans Martin, senior advisor to the Environment Canada Atmospheric Research Program. However, a study in Ontario using wind records in which the location of an air mass was traced back day by day to its source seemed to promise greater reliability. The United States and Canada, under the Memorandum of Intent on Transboundary Air Pollution, are also examining several potential computer models.

Thus, there is no question that sulfate particulates may be transported far from the emission point. Bowne concluded that attempts to apportion local measurements of sulfates among distant point sources by modeling of chemistry and especially the determination of trajectories have large uncertainties, but that regions and perhaps even states can be identified as source areas.

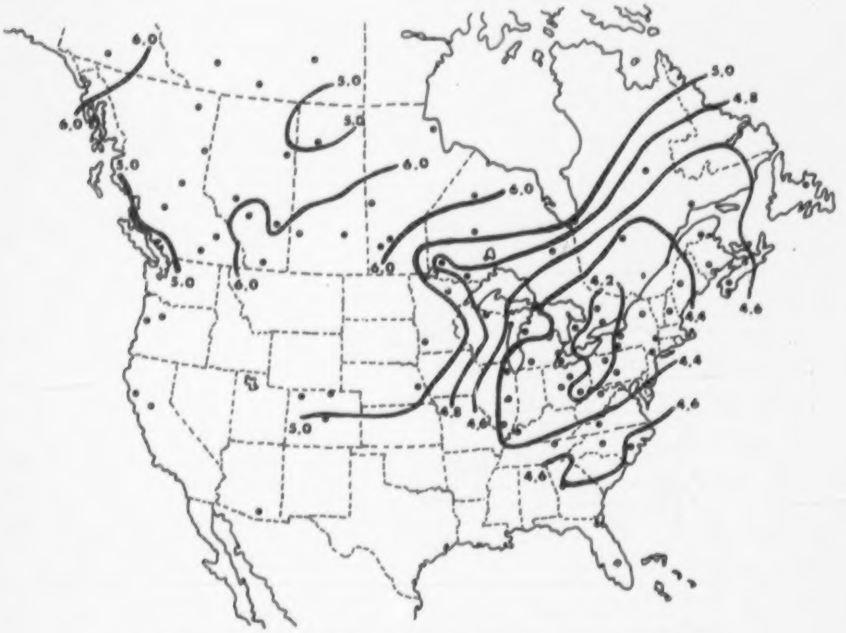

Figure 2. Mean annual pH of rain, 1979-1981 (National Research Council, 1981).

EFFECTS OF ACID RAIN

Effects on Soil and Water

In an invitational paper presented at the First International Symposium on Acid Rain, Frink and Voigt (1976) pointed out that, from its very inception, soil formation is an acidifying process. Because the amounts of acid in a year's worth of "acid rain" at pH 4.2 can be neutralized by about 50 lbs of limestone per acre per year, they concluded that the impact on managed agricultural soils would be negligible in comparison with the thousands of pounds of limestone regularly added to the soils in New England to neutralize acidity from fertilizers and biological decay of plant material.

Although early research on acid rain generally recognized that agricultural soil would not be affected, acid rain is thought to be causing severe acidification in mountainous landscapes in humid temperate climates with organic-rich, thin mineral soils developed from highly siliceous bedrock under coniferous forests and heaths. Acidification of these soils in the Adirondacks, northern New England, southeastern Canada, and Scandanavia is said to be an early warning of eventual acidification of lowland watersheds with deeper soils of greater buffering capacity as in Connecticut.

Krug and Frink (1983) have reviewed much of the literature on the effects of acid rain on soil and water, and in testimony to the Task Force stated that much of the acidification that has been observed in lakes can be attributed to the acidity produced by the formation of podzols and associated peaty soils under aggrading forests. The pH of the humus and upper mineral horizons (if present) is typically less than pH 4 and can acidify runoff regardless of the pH of the rain. Acid forest soils typically contain a reservoir of hydrogen ions that is 10,000 times greater than the hydrogen ions in acid rain. Since soil cannot distinguish between hydrogen ions from acid rain and hydrogen ions from all other sources, Krug and Frink conclude that significant acidification of forest soils by acid rain is unlikely. However, Krug and Frink (1983) also note that land use, soils and acid rain need to be examined on a watershed-by-watershed basis in order to determine the relative effects of these sources of acidity on lakes and streams.

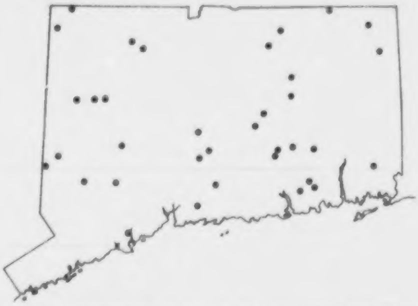

Figure 3. Locations of 35 lakes in Connecticut tested for alkalinity (The Connecticut Agricultural Experiment Station).

Similar conclusions are contained in the recently published Proceedings of the Acid Precipitation Research Needs Conference in New York (1982): "Acidification of Adirondack lakes may be related to long-term natural trends accelerated by acid rain. There is a need to quantify and differentiate between these two acidification processes."

The final report of the SNSF-project in Norway (Overrein et al., 1980) acknowledges that runoff from

Table 2. Connecticut Ponds included in U.S. Fish and Wildlife Service study of New England lakes.

Size Acres	Code	Pond	Town	Present[1] pH	Present[1] Alkalinty	Historical[2] pH	Historical[2] Alkalinity	Year
17.5	1147	Bigelow Pond	Union	6.24	84	6.4	—	1965
55	1148	Blue Pond	No. Stonington	6.64	152	—	—	—
85	1149	Burr Pond	Torrington	6.50	126	6.0	424	1940
2.5	1150	Darling Pond	Chaplin	6.02	94	—	—	—
7.5	1151	Emmons Pond	Hartland	4.60	6	6.0	—	1963
40	1152	Griggs Pond	Woodstock	6.37	128	—	—	—
72.5	1154	Holbrook Pond	Hebron	6.78	264	6.6	—	1954
17.5	1153	Howells Pond	Hartland	5.48	43	6.8	82	1953
32.5	1155	Millers Pond	Durham	5.56	30	—	—	—
15	1101	Mohawk Pond	Cornwall, Goshen	6.50	122	6.6	82	1953
27.5	1156	Norwich Pond	Lyme	6.76	244	7.1	—	1973
17.5	1157	Potters Pond	Woodstock	6.14	90	—	—	—
7.5	1158	Spring Pond	Granby	7.10	408	—	—	—
0.5	1102	Straits Pond	Warren	6.58	120	—	—	—
70	1159	Uncas Pond	Lyme	6.82	154	6.6	—	1954
25	1160	Whitmans Pond	Thompson	5.02	25	—	—	—

[1] Mean of two samples of surface water, October-December, 1980. Alkalinity in μeq/l. Data of Haines (1982).

[2] Data files, Connecticut Department of Environmental Protection. Measurements were generally made during summer months when the pH may be high, making direct comparison difficult.

acid soils will be acid and can affect the pH of lakes and streams. The report also notes that acidification of lakes and streams predates acid rain, and that acidification of soils due to changes in land use can contribute to acidification of fresh waters.

In Connecticut, a comparison of alkalinity of 20 lakes measured in 1937-1939 and again in 1973-1974 does not show significant changes in alkalinity (Norvell and Frink, 1975). This study has been expanded to include some 70 lakes, with earlier data available for 35. The locations of the lakes are shown in Fig. 3. The results do not show significant decreases in alkalinity (Fig. 4). The one lake where the alkalinity appears to have decreased from about 2.4 to 1.6 meq/l is actually a run-of-the-river impoundment (Lake Housatonic) where the alkalinity is affected by flow and waste water discharges. A number of lakes with low alkalinities (less than 0.5 meq/l) appear to show decreases, but this is probably within experimental error.

Haines presented testimony concerning the pH of a number of small lakes in Connecticut with relatively undisturbed watersheds (Table 2). For the eight lakes with historical data on acidity (1940-1973), five showed a decrease in pH. For three lakes with alkalinities measured between 1940-1953, one showed an increase and two showed a decrease. The pronounced acidification of Emmons Pond is puzzling and may be due in part to natural processes of acidification in the watershed (Haines, personal communication to C.R. Frink, November 1, 1982).

Effects on Vegetation

In describing the effects of air pollutants on vegetation, Smith (1981) suggested that the complex interactions could be divided into three classes:

- Class I. Low dose. Vegetation and soils serve both as sources and sinks for air pollutants. Depending on the pollutant, the impact may be undetectable (innocuous effect) or stimulatory (fertilizing effect).
- Class II. Intermediate dose. Individual species of trees and other vegetation may be subtly but adversely affected. These effects could include reduced productivity, changes in species composition, and increased damage from insects or disease.
- Class III. High dose. Acute morbidity or mortality of specific trees and consequent impacts on erosion, climate and other changes in the ecosystem.

As with others providing information to the Task Force, Smith stressed that acid rain is not a synonym for air pollution. He stated that sulfur dioxide, oxidants (ozone) and trace metals have particular importance in Connecticut, and that Connecticut is also within a zone of high acid deposition. The impact of present levels of air pollutants on forests and agricultural crops in Connecticut was described by Smith as Class II or subtle stress. The interaction of acid deposition with microbial plant pathogens and insect pests is likely to be one of the most important Class II effects (Smith et al., 1982).

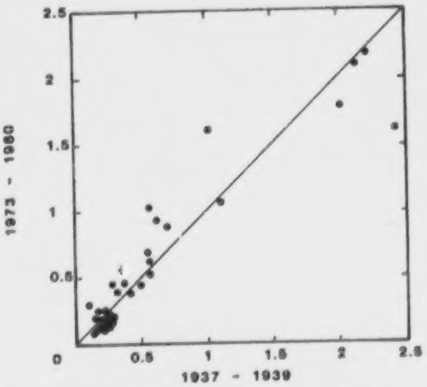

Figure 4. Alkalinity in meq/l for 35 Connecticut lakes (The Connecticut Agricultural Experiment Station).

Bormann discussed impacts of air pollution on the New England landscape with the Task Force, also emphasizing that acid rain is only one of many air pollutants that interact with other substances to damage the environment. Bormann indicated that it was possible to damage plants with acid rain in laboratory experiments, but that such damage was difficult to detect in the field. He expressed concern, however, that "large-scale genetic, biological, and ecosystem changes are probably occurring under current levels of air pollution stress."

Effects on Fish

According to Haines (1981) and Haines and Schofield (1980), continued exposure to low pH is not likely to kill adult fish in acidified lakes. Sudden exposure caused by acidified spring runoff seems to kill fish at higher pH values than chronic exposure to gradual increase in acidity. More likely symptoms are reduced growth, skeletal deformities, and especially reproductive failure. This in turn may lead to reduced species diversity or outright extinction of susceptible species.

The mechanism of toxicity to fish in acidified waters is not clear. The effects may be due to the hydrogen ion itself, or to aluminum and other metals leached from acid soils, or to synergistic interaction between acid and metals. Different strains of fish, particularly trout, differ in their tolerance of acidity and perhaps can provide resistant strains that will survive and grow in acidified waters (Haines, 1981).

To date, there are no reports of damage to fish in lakes in Connecticut. In testimony before the Task Force, Haines indicated that the greatest threats to Connecticut lakes are eutrophication and chemical pollution. The increased eutrophication of Connecticut's lakes is well documented (Norvell and Frink, 1975), as is the pollution of the lakes on the Housatonic River with PCBs (Frink, et al., 1982).

Effects on Structures

Yocum (1981) summarized the types of damage to materials that can be caused by air pollution as shown in Table 3. In testimony to the Task Force, Yocum indicated that acid rain itself has little effect on material damage. Most damage is caused by dry deposition or sorption of gases, particularly SO_2 and NO_x, which then react with dew or other moisture. Other environmental factors contributing to damage are sunlight, temperature, freezing and thawing, microorganisms and salt.

Damage to buildings and statues that is visible today is likely due to events 30 years earlier, according to Yocum. He also indicated that damage to materials has declined somewhat in the past few years.

Because of the relatively short residence time of SO_2 and NO_x in the atmosphere, damage to structures is more likely to be caused by local rather than long range sources (Yocum, 1981).

Effects on Health

Human exposure to acid rain takes three forms: breathing of air which contains aerosols and particles, consumption of drinking water, and direct contact with rain. Health effects have been studied in many ways. The principal methods reviewed here are the response of humans to specific levels of pollutants in laboratories, statistical analysis of the correlations between pollution levels and health records (morbidity and/or mortality), and analysis of death and sickness rates during episodes of very high pollution levels.

The episodes of fog in London in 1952 and Donora, Pennsylvania in 1948 dramatically show the effects of very high levels of air pollution. In these two episodes, high levels of sulfur oxides and particles coupled with atmospheric stagnation caused thousands of people to become ill with respiratory ailments and significantly raised the death rate for a short period of time. As a result of these episodes, steps were taken to regulate emissions and this magnitude of air pollution and effects on health is no longer likely.

There have been a large number of statistical studies of the correlations between levels of specific pollutants and public health. These studies are usually very complicated and the results only show correlation which does not prove cause and effect. We summarize the results of four of these statistical studies below.

A London study (Douglas and Waller, 1966) followed four thousand children from birth to age fifteen. The study showed that lower respiratory infections were consistently related to pollution and the severity of the

Table 3. Air Pollution Damage to Materials (Yocum, 1981).

Materials	Type of Damage	Principal Air Pollutants	Other Environmental Factors	Methods of Measurements	Mitigation Measures
Metals	Corrosion, tarnishing	Sulfur oxides and other acid gases	Moisture, air, salt	Weight loss after removal of corrosion products. Reduced physical strength, change in surface conductivity.	Surface plating or coating. Replacement with corrosion resistant material.
Building Stone	Surface erosion, discoloration	Sulfur oxides and other acid gases, particulate matter	Moisture, temperature fluctuations, salt, vibration, microorganisms, CO_2	Surface reflectivity, measurement of dimensions.	Cleaning and sand blasting. Impregnation with resins, replacement.
Paint	Surface erosion, discoloration	Sulfur oxides, hydrogen sulfide, ozone, particulate matter	Moisture, sunlight, microorganisms	Weight loss of painted panels, surface reflectivity.	Repainting, replacement with more resistant paint.
Textiles	Reduced tensile strength, soiling	Sulfur oxides, nitrogen oxides, particulate matter	Moisture, sunlight, physical wear	Reduced tensile strength, reduced fluidity (cotton), surface reflectivity.	Replacement
Textile Dyes	Fading, color change	Nitrogen oxides, ozone	Sunlight	Reflectance and color value measurements.	Replacement
Paper	Embrittlement	Sulfur oxides	Moisture, physical wear	Decreased folding resistance.	Synthetic coatings, storing indoors in pollutant-free atmosphere.
Rubber	Cracking	Ozone	Sunlight, physical wear	Loss in elasticity and strength, measurement of each frequency and depth.	Add antioxidant to formulation. Replace with more resistant materials.
Leather	Weakening, powdered surface	Sulfur oxides	Physical wear	Loss in strength.	Store in indoor pollutant-free environment, replace.
Ceramics	Changed surface appearance	Acid gases, HF	Moisture	Loss in surface reflectivity.	Protective coating, replace with more resistant material.

illness increased with the level of pollution. The socioeconomic status of the children was not important.

In 1970, Hodgson found that mortality from respiratory and heart disease in New York City correlated with air pollution levels (Hodgson, 1970).

In 1977, Lave and Seskin showed that in the largest United States cities (not Hartford), there is a close relationship between mortality rate and pollution levels of sulfates, sulfur dioxide, suspended particles, and possibly nitrous oxide. There was no consistently significant relationship for levels of nitrate, nitrogen dioxide, carbon monoxide, and hydrocarbons (Lave and Seskin, 1977).

In 1979, Mendelsohn and Orcutt studied two million death certificates from 1970 and found "Some pollutants, especially sulfates, are closely associated with many deaths, whereas other pollutants, especially ozone and nitrogen dioxide have no apparent effect on expected lifetimes." Quoting further: "The dose-response curves, even for relatively low measurement levels in the sample, appear to be linear. For all practical purposes, there is no evidence of a lower threshold effect for any of the pollutants." If the results of this study are extrapolated to the entire country, the authors predict that a total of 140,000 deaths a year, which is 9% of all fatalities, are attributable to air pollution. The study reported that mortality due to air pollution in New England is about twice that in the rest of the country. The maximum damage was found to occur in eastern Ohio where sulfate concentrations were also close to a maximum.

Many studies have linked sulfate levels to respiratory problems. Recently, breathing sulfuric acid aerosols has been found to alter mucociliary clearance rates in healthy non-smoking adults (Lippmman, et al., 1981). Sulfate levels above 6-10 $\mu g/m^3$ cause increased asthma attacks (EPA, 1974). Higher sulfate levels have been linked to daily mortality increases, acute lower respiratory diseases in children, and aggravated heart and lung diseases in the elderly (EPA, 1974). Levels cited in these studies are exceeded in the Northeastern U.S.

The most serious effects of air pollution on health are due to the presence of respirable particles approximately 1 micron in size which can lodge in the lung. Some of these particles are sulfate aerosols produced by the reaction of SO_2 in water to form H_2SO_4, which is then neutralized in part by ammonia in the atmosphere (Tanner et al., 1981). Levels of respirable particles are not controlled by existing federal particulate standards, which are based on total particulate levels with no size distinction. Emission control technologies have therefore focused on removal of large particles to achieve total particulate standards, leaving respirable particles relatively unaffected.

In terms of direct external human contact, concentrations of acids in acid rain are sufficiently low that burns and rashes are not observed. The long term effects of direct contact with low levels of acid precipitation, if any, are not known at the present time.

Potential indirect effects of acid rain include consumption of acidified drinking water and consumption of fish from acidified water bodies. Acid water has been shown to dissolve lead and copper from water pipes. However, proper pH control of community water supplies would normally prevent this from occurring (Northeast Damage Report, 1981, p. 51). It is suspected that acidic water is partially responsible for dissolving mercury and lead minerals which accumulate in fish. This has been observed in New York (Fuhs, 1979), but should not occur in Connecticut lakes which are less acidic.

In summary, there can be adverse health effects from the pollutants which accompany and make up acid rain. The magnitude of the effect depends on the amount of exposure, i.e., dose. Respirable particles, sulfur oxide aerosols, and toxic heavy metals are the species of highest concern. The air and water quality standards in Connecticut offer some degree of protection by limiting the amount of sulfur dioxide, total suspended particles and heavy metals in air and water. In most cases these standards do not completely address the control of those species which most directly concern health.

STUDIES OF ACID RAIN IN CONNECTICUT

Atmospheric Deposition Monitoring

The Connecticut Department of Environmental Protection and the US Geological Survey initiated a cooperative atmospheric deposition monitoring program in 1981 to assess the chemistry and distribution patterns of "acid rain" in Connecticut. Objectives of the program are to determine differences across the state, to determine relationships between atmospheric deposition and air mass movements, and to provide baseline data to determine trends and estimate loads. Monitoring site locations, collection methods, and analytical methods are consistent with criteria established by the National Atmospheric Deposition Program.

Three monitoring sites have been selected—Quinebaug fish hatchery near Wauregan; Salmon River State Forest near Leesville; and Morris Reservoir near Thomaston. The Wauregan site was activated in October 1981, and the other two sites became operable in October 1982. The program is designed for collection of wet deposition during selected storms and collection of dry deposition samples every two months. Samples will by analyzed for pH, specific conductance, major anions and cations, major nutrients and selected heavy metals. As of October 1982, 13 samples had been collected and analyzed for pH and conductance, and four samples had been collected and analyzed for chemical constituents. Data will be reported in the annual US Geological Survey report series and an interpretative report will be published in late FY 84.

Effects of Precipitation and Snowmelt on Surface Water Quality

The Connecticut office of the US Geological Survey has developed a proposal to study the Salmon River watershed to determine whether precipitation and snowmelt alters the water quality characteristics of the Salmon River, Blackledge River, and Dickinson Creek. The study would involve simultaneous sampling of surface water, precipitation and snow cores. The proposal was submitted for consideration for federal research funds.

Effects of Acid Rain on Drinking Water Supplies

The New England Water Works Association and the Environmental Protection Agency are presently conducting a cooperative study of the effects of acid rain on water supplies in New England. Objectives of this study are to determine if changes in water supply quality occurred with the advent and increase in acid rain; to evaluate trends with respect to corrosion, dissolution of metals and asbestos, bacteriological quality, and taste and odor organisms; and to estimate the economic impact of acid rain on public water supplies. The study involves a review of historical data and records as well as collecting samples of raw and finished water. Approximately 25 Connecticut water supplies are included in this study. A report of this study is due in 1982.

Effects of Acid Rain on Lakes

The US Fish and Wildlife Service Research Laboratory in Orono, Maine is presently conducting a water quality study of acid-sensitive lakes in New England. Lakes selected for the study were those likely to be susceptible to acidification due to watershed size, geological conditions, and land use. The study involves sample collection and analysis in 1980 and 1981, and a review of historical data. Sixteen ponds in Connecticut are included in the study (Table 2). The results to date were discussed earlier.

Effects of Acid Rain on Soil and Water

The Connecticut Agricultural Experiment Station in New Haven has studied changes in Connecticut's forests in plots established in 1927. These studies will be expanded to include changes in soil properties that have occurred as the forest matures. Additional studies will be made of lakes in upland landscapes with highly coniferous watersheds where the greatest acidification of soils has been observed.

Effects of Acid Precipitation on Amphibians

Pierce of Connecticut College is presently completing a research project on the effects of acid rain on the wood frog, ***Rana Sylvatica***. One objective is to examine the acid tolerance of three life states—embryo, larva, and metamorphosing larva. Another part of the project is a study of the spatial and seasonal variations of pH in a pond where wood frogs breed. The project also is examining relationships between pH of rain and pH of the breeding pond. A report is scheduled to be completed by the end of 1982.

Air Quality Monitoring

The Connecticut Department of Environmental Protection Air Compliance Unit maintains an ambient air quality monitoring network which routinely measures many parameters associated with acid rain. Greatest emphasis is placed on six pollutants for which Environmental Protection Agency standards have been set—total suspended particulates, sulfur dioxide, ozone, nitrogen dioxide, carbon monoxide, and lead. Approximately 40 stations are monitored throughout the state. Sulfur dioxide and nitrogen dioxide are measured continuously, and total particulates are measured once a week. In addition, nitrate, sulfate, chromium, and 10 metals are measured on a quarterly basis.

The Department of Environmental Protection has also participated in the Environmental Protection Agency Inhalable Particulate Network in recent years. Under this program, the Department of Environmental Protection has collected samples from stations in Connecticut and has sent samples to the national laboratory for measurement of respirable particles.

Effects of Acid Rain on Surface Water Quality

Historical and recent Connecticut surface water quality data is being used by the aquatic effects research program of the Federal Interagency Task Force on Acid Precipitation. A primary objective of this study is to quantify the extent of acidification and sensitivity of lakes, streams, and groundwaters of the United States. This will include a determination of trends in the acidification of surface waters, and an assessment of future acidification. Principal participants are the Environmental Protection Agency and Brookhaven National Laboratory. This program has produced a national map of surface water sensitivity based on total alkalinity.

CURRENT REGULATION OF ACID RAIN

The Federal Program

As now constituted, the federal Clean Air Act does not address the acid rain issue. The control of acid rain which now exists is indirect, a byproduct of pollution abatement strategies designed to deal with other pollution problems. Failure to deal with acid rain and long range transport of pollution in general primarily results from the fact that long range transport of pollution has only come to be a subject of public debate since the Clean Air Act was last amended in 1977. Whether these issues will be addressed in the current revision of the Act remains a subject of some controversy.

The pollution abatement programs established under the federal Clean Air Act were intended to deal with localized air quality problems close to sources of pollution. To this end, the Environmental Protection Agency has established National Ambient Air Quality Standards (NAAQS) for seven major pollutants including sulfur and nitrogen oxides. NAAQS are the basis for most of the nation's air pollution control program. The inadequacy of these localized pollution standards to deal with acid rain was noted by the National Commission on Air Quality which pointed out that the key factor associated with acid rain is "not ambient pollutant concentration but rather total pollutant loading which is only indirectly linked to ambient concentration." This approach means that large amounts of pollutants may be generated in certain localities without violation of ambient air standards if there is sufficient dispersion. Thus, even a stringent local program of control may still result in long range pollution problems. In fact, some commentators have pointed out that strategies to disperse local pollution, such as tall stacks, have contributed to the acid rain problem. The existing NAAQS have also been cited as problematical in dealing with acid rain because standards exist only for sulfur dioxide and nitrogen dioxide gases, whereas sulfates and nitrates, the derivative particulate compounds of these gases which apparently react with water vapor in the formation of acid rain are only indirectly regulated.

In accordance with the Clean Air Act's focus on local ambient pollution concentrations, states are required to prepare individual State Implementation Plans (SIP) to demonstrate how the NAAQS will be met in each state. Because the SIP process concentrates on control of sources within a state to meet federal standards, pollutants transported beyond state boundaries may escape regulation. According to the report of the National Commission on Air Quality, sections of the Clean Air Act that address interstate pollution have proved ineffective. Section 110(a)(2)(E) of the law requires that the Environmental Protection Agency not approve any SIP that allows pollution which would "prevent attainment or maintenance" of ambient air standards in another state. However, the report notes, no regulations have been issued to clarify the legislation and therefore there is no guidance on the relative responsibilities of polluting and receiving states. Section 126 of the Act permits state or local governments to petition the Environmental Protection Agency to enforce Section 110. However, due to the technical and political complexity of these cases, no petition has been granted and some have been awaiting a decision for years.

Despite the inadequacies of the Clean Air Act, several existing control strategies may indirectly address acid rain by reducing local pollution or preventing further deterioration. These include the non-attainment program, which requires reduction of emissions in an area which does not meet the NAAQS. In addition, the Prevention of Significant Deterioration (PSD) program which seeks to protect air in areas that meet federal standards by requiring more stringent standards for new or modified pollution sources, and the new source performance standards which impose stricter controls on certain categories of polluters, will reduce the future growth of acid rain pollutants although they will not reduce current levels.

Connecticut's Program

Connecticut's air pollution program is largely a response to the federal Clean Air Act. Although emissions of sulfur and nitrogen oxides in Connecticut will probably not cause acid rain in Connecticut, long range transport of these pollutants adds to overall atmospheric loading which may result in acid rain elsewhere. For many years, Connecticut had by far the toughest statewide sulfur-in-fuel requirement in the nation. No fuel could be burned in the state that had more than 0.5% sulfur. This put Connecticut in compliance with the sulfur NAAQS by a wide margin. This standard was recently altered to permit burning of fuel containing 1% sulfur by business and industry. According to the Department of Environmental Protection, this change in the standard will increase sulfur oxide emissions from about 73,000 tons per year to somewhat over 123,000 tons per year. For purposes of perspective the Department of Environmental Protection notes that emissions of sulfur oxides from just the Port Jefferson and Northport power plants on Long Island produce over 150,000 tons per year, more than all Connecticut sources combined. Another recent development concerning sulfur dioxide was the repeal of Connecticut's stricter property related (secondary) sulfur dioxide standard which will cause some additional deterioration of air quality. Connecticut was one of the few states to have such a standard. Since Connecticut remains in attainment for sulfur dioxide, certain major new air pollution sources must also obtain a PSD permit which will subject them to stricter review.

Connecticut has attained the NAAQS for oxides of nitrogen. Although localities of the state exceeded these standards in the early 1970s, controls on the stationary sources have caused the state to reach attainment. In the future, new large sources will have to obtain PSD permits. In addition to stationary sources, motor vehicles also emit oxides of nitrogen. Connecticut has chosen to leave control of such emissions to the Federal Motor Vehicle Emission Control Program which requires manufacturers to produce vehicles emitting less nitrogen oxides. Connecticut has not chosen to regulate nitrogen oxides under the Automobile Inspection/Maintenance Program since the state is at attainment.

STATUS OF FEDERAL LEGISLATION ON ACID RAIN

Background

Congressional action addressing the acid rain problem must be examined in the context of the debate over reauthorization of the federal Clean Air Act. Final action to reauthorize the Act has not been taken by either the full House or Senate, but significant provisions directed at mitigation of acid rain have emerged from the Senate Environment and Public Works Committee. For example, the Senate bill requires a substantial reduction in sulfur dioxide emissions in a 31-state region. The Senate Committee voted 15-1 on August 19, 1982 to report its Clean Air Act amendments to the full Senate for consideration. However, the Senate has yet to take up this new bill.

The House bill on the Clean Air Act issue differs substantively from the Senate version and does not recommend a regulatory control approach to acid rain. The House version, currently in a markup phase in the House Energy and Commerce Committee, basically adopts a continued research approach to the issue of acid rain.

Senate Bill Status

The bill reported out by the Senate Environment and Public Works Committee is an amended version of S-1706, originally introduced by Senator Mitchell of Maine. It would require an 8 million ton reduction below 1980 levels in existing sources of sulfur dioxide emissions within a 31-state eastern acid rain mitigation region. States included are Alabama, Arkansas, Connecticut, Delaware, Florida, Georgia, Illinois, Indiana, Iowa, Kentucky, Louisiana, Maine, Maryland, Massachusetts, Michigan, Minnesota, Mississippi, Missouri, New Hampshire, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, South Carolina, Tennessee, Vermont, Virginia, West Virginia, and Wisconsin, as well as the District of Columbia. These states would be given 12 years to achieve the required reductions in sulfur dioxide emissions (The original S-1706 established a 10 year timetable). State Implementation Plans (SIP) required under the Clean Air Act would have to be revised to contain enforceable emission reduction steps and approved by EPA within four years. If states failed to reach agreement within 18 months on the allocation of SO_2 reductions, EPA would make the decision. States would also be allowed to trade emission reductions under the bill.

Acid rain research would continue under the bill with the Inter-agency Task Force required to submit annual progress reports to Congress, plus two comprehensive reports that include recommendations for reducing acid rain. The Senate bill also recommends a five-year authorization of the Clean Air Act.

House Bill Status

House activity on the Clean Air Act and the related issue of acid rain centers in the House Energy and Commerce Committee. The House proposal (HR-5252) accelerates research efforts established under the Energy Security Act of 1980 from ten years to five years. That federal law (P.L. 96-294(1980)) established a comprehensive acid precipitation program and carbon dioxide study to be carried out by an Acid Precipitation Task Force, jointly chaired by the Secretary of Agriculture and the administrators of the Environmental Protection Agency and the National Oceanic and Atmospheric Administration.

The House bill also requires the Environmental Protection Agency to report on alternative control strategies for addressing the acid rain situation. This includes precombustion fuel treatment and inherently low-polluting combustion technologies such as atmospheric fluidized bed combustion. (These control strategies, as well as the accelerated research approach, were originally offered in HR-5055).

The House Energy and Commerce Committee has taken no action on HR-5252 since mid-August. It is unlikely that a House bill will contain regulatory measures directed specifically at acid rain.

CONCLUSIONS

Nature and Sources of Acid Rain

There is little doubt that rain in Connecticut and elsewhere in the Northeast has been acidified by increased emissions of sulfur dioxide and nitrogen oxides. The increased emissions of sulfur dioxide can be attributed largely to increased combustion of fossil fuels. Nitrogen oxides are produced during high temperature combustion regardless of the composition of the fuel and the observed increases can be attributed largely to automobiles as well as stationary combustion sources.

In addition to acidifying rain, the gaseous oxides of nitrogen and sulfur may react directly with materials they contact, or they may react with other substances to produce particulate aerosols. Thus, acid rain is a mixture of acids dissolved in water, reactive gaseous oxides, and fine particulate sulfate and nitrate aerosols. In addition, air contains other pollutants such as ozone, hydrocarbons and heavy metals that also may be harmful. Unfortunately, these various pollutants are often grouped together under the heading of "acid rain," which has become a subject of national and even international environmental concern.

The sources of acid rain and other air pollutants in Connecticut are not readily quantified. This is due in part to the varied components of acid rain: if damage is caused largely by gaseous SO_2, for example, its relatively short residence time in the atmosphere suggests that local sources are important. Fine particulate aerosols, on the other hand, can be transported over longer distances. The more distant the source, the more difficult it becomes to specify that source. Present models that attempt to estimate the trajectory of polluted parcels of air have errors of the order of 50% of the distance involved. However, it is clear that regions and perhaps even states can be identified as source areas.

Rain in Connecticut has an average pH of about 4.3-4.4, which is highly acidic compared to unpolluted rain with pH 5.6. The area of most highly acidified rain (pH~4.2) lies to the west of Connecticut, covering the general area of western Pennsylvania, western New York, eastern Ohio, and southeastern Ontario. Measurements of sulfate and nitrate deposition confirm that this area is the center of acid deposition. Because large amounts of sulfur dioxide and nitrogen oxides are produced in the 28 states east of the Mississippi, it is reasonable to conclude that, once again, man has fouled his own nest.

Effects of Acid Rain

To date, the effects of acid rain on the environment of Connecticut can be summarized as subtle. The soils of Connecticut are generally well buffered and show no evidence of acidification by acid rain. Measurements of the alkalinity of 35 lakes in Connecticut show little or no change since earlier measurements in 1937-1939. Similarly, there is no evidence that fish in our lakes have been affected by acid rain, but there are 1000 lakes in Connecticut large enough to have names and some changes may have gone undetected. There is no evidence of damage to agricultural crops, and little or no reason to believe that our forests have been adversely affected to date. However, concern has been expressed that current levels of air pollution may cause genetic, biological and ecosystem changes that have yet to be identified.

The effects of acid rain on structures in Connecticut are evident in the weathering of some statues and other building stone. The damage is caused largely by the sorption of gaseous oxides, particularly sulfur dioxide, which then dissolves in dew or other moisture to produce sulfuric acid.

There is little evidence of any direct effect of acid rain—i.e. increased acidity of rainfall—on human health. The notion that acid rain will burn skin or dissolve one's clothing has no basis in fact. However, there is no question that some forms of air pollution are harmful to health. Specifically, fine particulate aerosols can lodge in the lung and cause respiratory problems. A portion of these aerosols are acidic due to the presence of sulfur oxides. The association between these air pollutants and human health is statistical, rather than clinical, with one published study indicating an increase in mortality in New England due to air pollution. The precise role of sulfate aerosols in this complex air pollution problem is not known.

RECOMMENDATIONS

The Task Force finds that there is a serious need for increased public understanding of the sources and effects of acid rain in Connecticut. In addition, the Task Force has identified areas where there are significant gaps in our knowledge. Finally, the Task Force recommends some regulatory activities that may aid in controlling acid rain.

Public Awareness. The Task Force recommends that the Department of Environmental Protection, Department of Health Services, and other appropriate agencies undertake educational programs that will inform the public of the facts concerning acid rain.

Increased Knowledge. The Task Force recommends that further studies of acid rain in Connecticut should include the following in order of priority:

- Methods for monitoring total suspended particulates should be improved so that sulfates and particle size can be measured. As satisfactory methods are developed, the frequency of sampling should be increased. This will assist further epidemiological studies that are needed to determine the health effects of size and acidity of respirable particulate matter.
- Monitoring of pH of rainfall should be expanded to include pH of rivers and streams, particularly during spring runoff into head water streams. Special attention should be given to sensitive areas such as salmon spawning and stocking locations.
- Studies of lakes should focus on those in highly forested watersheds where acidification seems most likely. These studies should include effects of acidification on growth of forests where possible.
- Monitoring of sulfur dioxide should continue to determine if recent changes in allowable sulfur contents of fuel have resulted in changes in concentrations of sulfur dioxide in the air.
- Transport models should be developed with sufficient accuracy to predict movement of air pollutants so that effects of regulatory changes can be determined.

Regulatory Action. The Task Force recognizes that Connecticut is a national leader in regulating emissions of sulfur dioxide. The Task Force also realizes that many of the regulatory actions needed to reduce the effects of acid rain in Connecticut are federal as well as state. However, significant amounts of sulfur oxides are produced in Connecticut by burning of fossil fuels, and significant amounts of nitrogen oxides are produced in Connecticut from automobiles. Changes in current regulations on sulfur content of fuels or on emissions from automobiles should be carefully evaluated in terms of effects that may be expected.

The Task Force recommends that the General Assembly memorialize Congress to strengthen the Clean Air Act with particular reference to regulation of particle size of total suspended particulates, and to address the problem of regional transport of pollutants into Connecticut.

ATTACHMENT I

Persons Providing Information to the Task Force

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Mr. John Kasprak, Research Attorney, Office of Legislative Research, Connecticut General Assembly, Hartford, CT.

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Mr. John E. Yocum, Vice President and Chief Consulting Engineer, TRC Environmental Consultants, Inc., East Hartford, CT.

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TESTIMONY ON THE ENERGY EFFECTS OF ACID RAIN CONTROL

ROBERT E. WAYLAND AND T. JAMES GLAUTHIER

SUBMITTED TO THE
U.S. SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

APRIL 30, 1984

We are pleased to submit written testimony to the Committee on Energy and Natural Resources on the effects that acid rain controls would have on the nation's energy supply. Our statement discusses the major implications of such controls for the coal, oil and electricity sectors of our energy system.

We have attempted to address these issues broadly, recognizing the wide range of legislative and regulatory proposals that have been made for acid rain control. In many instances we have illustrated our comments with quantitative estimates that are specific to HR3400, because we have evaluated that bill more extensively than any other. It is our hope that those estimates will help to put the magnitude of potential effects into sharper focus, and that they will serve as reference points for discussion of how other proposals would differ.

The topics covered on the following pages address the four major questions, namely the implications of acid rain control proposals upon: (a) the cost of electricity; (b) our Nation's efforts to foster greater coal utilization as an alternative to oil imports; (c) our Nation's coal distribution system; and (d) our Nation's electricity reliability.

Our testimony is based on the analyses we've conducted for the electric utility industry of the economic and energy aspects of various acid rain control proposals. The principal sponsor of that work has been the Edison Electric Institute.

If the Committee or its staff has any questions on our statement or on other aspects of the legislation that falls with our area of expertise, we would be happy to provide additional information. Our statement follows.

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Cost of Electricity

Compliance with acid rain legislation will increase the cost of electricity substantially in some states. These increases will exacerbate the economic difficulties of these states and alter existing patterns of production, employment and investment. We estimate that the 1985 net present value of HR3400 compliance-related outlays from 1985 to 2008 would be $62 billion[1]. In current dollars, the bill's total cost would come to $222 billion over the same time period.

The "levelized" cost of $8 billion per year will noticeably affect customers' bills, even spread over the entire country. This increase represents 6.6 percent of the 1982 total electric utility revenues of $121 billion.

The pattern of incremental revenue requirements that would result from compliance with HR3400 indicates that in 1993, the first full year of compliance, revenue requirements would increase by about $13 billion. When compared to 1993 "base line" revenues (1982 actual revenues adjusted for inflation and load growth) the nationwide revenue increase is on the order of 5 percent.

Of course, compliance costs will not be spread equally across the nation. For a 10 million ton reduction allocation based on excess emissions, nine states would be required to achieve more than three quarters of the total reduction, and two of these states, Ohio and Indiana, would have to reduce emissions by 2.8 of the 10 million ton national total.

Cost sharing proposals, such as those contained in HR3400, would reduce the regional disparities in rate increases but only slightly. HR3400's cost sharing fund would reduce incremental costs borne by electric utility customers in thirteen states that would receive more out of the fund than they would pay into it. However, in those states, the costs would be offset generally only by 20 percent or less by the fund. The remaining 35 states would pay more into the fund than they would receive from it.

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[1] A 12 percent discount rate was assumed for net present value and levelization calculations.

Table 2 provides representative rate increases for the 11 states with the highest average price effects. All of these states would receive more from HR3400's cost sharing fund than they would pay into it. The reported rate increases have been reduced by the net receipts from the fund.

Table 1

REPRESENTATIVE RATE INCREASES FOR HIGH IMPACT STATES

		Typical Annual Bill Increases					
		Residential		Commercial		Industrial	
	Average Price Effect (mills/kWh)	(dollars per year)	(Percent Over Actual 1982 Rates)	(dollars per year)	(Percent Over Actual 1982 Rates)	(dollars per year)	(Percent Over Actual 1982 Rates)
Missouri	12.4	$109	22%	$713	23%	$11,716	29%
Indiana	11.8	115	21	505	26	15,046	26
Kentucky	8.9	89	17	363	17	31,081	24
Ohio	10.7	86	16	592	17	18,310	26
Tennessee	6.6	94	14	163	12	14,398	15
Wisconsin	7.4	59	12	347	12	23,931	17
West Virginia	5.5	49	10	260	11	5,510	13
Georgia	5.3	55	9	330	9	6,961	12
New Hampshire	7.8	53	9	188	9	11,671	12
Iowa	5.3	47	8	189	8	9,526	13
Illinois	5.9	42	8	308	8	20,986	12

Rate increases will affect industries to varying degrees depending on their geographical locations and their electricity-intensity. Table 3 provides an analysis of the bill increases for 20 industries in 10 states. Two industries, chemicals and primary metals, would pay more than half of the total industrial cost increases in these ten states. These two industries in these ten states alone would pay 13 percent of the nation's total bill for abatement.

Table 2

TOTAL HR3400 ANNUAL (LEVELIZED) BILL INCREASE BY INDUSTRY FOR TEN HIGH-IMPACT STATES

(millions of dollars)

Industry	MO	IN	KY	OH	TN	WI	WV	GA	IL	PA	Industry Totals
Food	12.77	15.86	3.97	18.20	7.39	12.64	0.46	6.17	17.61	10.11	105.25
Tobacco	0.00	0.00	1.64	0.00	0.36	0.00	0.00	0.00	0.00	0.21	2.20
Textiles	0.18	0.27*	0.96	0.99	4.69	0.47	0.06	20.24	0.24	2.80	30.70
Apparel	1.27	1.42	1.15	1.05	2.85	0.21	0.19	2.81	0.63	2.24	13.82
Lumber	1.13	2.67	1.05	2.34	1.51	2.13	0.44	2.92	0.00	3.26	16.46
Furniture	0.80	2.70	0.37	1.68	1.37	0.58	0.07	0.33	1.06	0.98	9.95
Paper	3.41	5.56	0.00	16.23	16.92	28.48	0.21	15.63	5.85	9.81	99.80
Printing	3.41	3.63	1.50	7.08	1.74	2.29	0.20	1.16	5.74	3.46	30.20
Chemicals	13.69	36.29	108.28	116.04	80.95	3.40	21.72	10.38	20.78	13.44	420.96
Petroleum	1.76	6.27	0.00	18.64	1.01	0.56	0.00	0.23	13.63	7.76	43.86
Rubber & Plastics	4.78	12.77	3.79	23.55	5.57	3.76	0.00	2.50	8.71	5.63	70.88
Leather	1.26	0.00	9.55*	0.00	0.85	0.63	0.00	0.00	0.12	0.44	12.85
Stone, Clay & Glass	10.05	13.15	1.82	23.76	5.62	1.13	2.48	5.26	6.45	13.86	83.76
Primary Metals	48.15	132.90	73.23	184.50	67.69	9.29	22.38	5.45	44.03	74.61	662.03
Fabricated Metals	7.67	10.96	3.20	34.53	4.28	7.45	0.63	2.13	12.18	8.62	91.66
Machinery Excl. Elec.	6.56	13.61	5.76	30.13	3.49	10.29	0.31	1.59	19.36	9.70	98.57
Electric Equipment	7.88	19.08	5.16	15.46	7.41	5.27	1.67	1.98	8.76	9.92	82.58
Transportation Equip.	11.42	20.74	2.86	37.57	2.86	3.83	0.13	3.37	4.40	5.44	92.61
Instruments	0.76	1.38	0.40	2.06	0.35	0.67	0.00	0.32	2.05	1.87	9.86
Misc. Manufacturing	0.75	1.07	0.40	1.66	0.84	0.56	0.01	0.66	1.57	1.41	8.90
State Totals	135.66	296.13	225.10	529.53	195.76	93.61	51.15	82.95	172.94	184.15	1966.98

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*estimate

Based on 1981 electricity consumption

Sources: 1982 Census of Manufactures, Fuels and Electric Energy Consumed, U.S. Department of Commerce, Bureau of Census

Expanded Executive Summary to Evaluation of H.R. 3400, The "Sikorski/Waxman" Bill for Acid Rain Abatement, TBS for EEI, January, 1984

Nation's Efforts to Foster Greater Coal Utilization as an Alternative to Oil Imports

Legislative and regulatory efforts to reduce acid rain are likely to affect the level of U.S. coal- and oil-fired generation because the relative cost of coal generation will increase, the reliability of coal-fired generation will decrease and additional capacity and energy requirements will stem from the use of scrubbers. Although some aspects of acid rain compliance would act to decrease oil-fired generation, the net result is likely to be a reduction in coal-fired generation for sales to ultimate customers, and an increase in oil-fired generation. The factors that will influence these changes and the direction of the changes are described below.

1. Compliance-related costs will cause the cost of electricity to increase, resulting in a decrease in total electricity, and, hence, coal and oil consumption nationwide. Since most oil-fired capacity meets peak or intermediate load requirements, declines in electricity consumption may decrease oil requirements relatively more than coal requirements.

   To conservatively estimate the magnitude of the effect of decreased electricity consumption on oil and gas consumption: if electric rates nationwide increase by 2 percent (see following discussion of costs) and customers are not very price sensitive, sales could decline by over 200 billion kWh per year. This decrease in electricity sales would have two components, decreases in energy use overall, and switching from electricity to other energy sources. The decline in electricity consumption leads directly to a decrease in the use of oil and coal used to generate electricity. However, since electricity is relatively more expensive, some consumers will substitute oil, gas or coal for electricity in their production processes, therefore increasing the demand for these fuels types.

2. The cost of coal-fired generation will increase relative to oil generation. Since utilities are currently paying three times as much for oil as for coal on a Btu basis, it is doubtful that this increase would be large enough to have a major effect on utilities' dispatch order, but, at the margin, some coal generation will be displaced. If 5 percent of the coal-fired energy affected by acid rain legislation were replaced by oil or gas from changes in the dispatch order, 35 billion kWh of additional oil- and gas-fired generation would result. This is about 8 percent of 1982 oil- and gas-fired generation.

3. Both the installation of scrubbers and the switching of fuels is likely to reduce the reliability of coal-fired units. The installation of retrofit scrubbers on pre-NSPS units frequently requires major modification of the unit and introduces an additional source of plant outage unless plants can bypass a malfunctioning scrubber. At an optimistic estimate of 95 percent scrubber reliability, we estimate that under HR3400, 24 billion kWh/year would be lost from these units due to reduced availability. Most of the replacement generation would be coal-fired, but some would result in increased oil consumption.

   The substitution of low-sulfur coal for high-sulfur coal in utility boilers can also cause reliability problems. Most boilers are designed with a particular coal specification in mind, and deviations from these specifications can cause a variety of problems to surface. As with scrubbers, some of the generation potential lost to outages would be replaced by coal, some by oil.

4. Total in-plant use of electricity would increase. An operating scrubber consumes about 5 percent of the power produced by the unit. We estimate that under HR3400, an additional 24 billion kWh/year would be required simply to run scrubbers. This generation would be provided by a combination of coal, oil, and gas units.

5. Technology-forcing provisions, such as those of HR3400's "Subpart 1," would likely lead to premature retirement of units which are too old or too small to economically install scrubbers, or with site-specific conditions which make scrubbing prohibitively expensive. We estimate that about 18,500 MW of coal-fired capacity and 550 MW of oil-fired capacity would be prematurely retired as a result of HR3400. The retirement of coal capacity represents a lost opportunity to generate 48.6 billion kWh/year. The replacement for this energy would come in large part from oil- and gas-fired units. These smaller, older units are generally loaded late in the dispatch order with only oil and gas units above them. Any decreass in their output would therefore be met by increases in oil and gas generation.

6. Coal conversions, life extensions, and upgradings might be encouraged by legislation requiring scrubbers. Under NSPS, if a company invests heavily in modifications to a unit, it may cause the unit to be considered a "new source" and the utility may have to install scrubbers. This requirement may inhibit companies from investing in coal plant life extensions, uprating their capacities, making them more efficient, or converting oil plants to coal. If some of these coal or oil plants were required to install scrubbers to comply with acid rain legislation, the incremental costs

of these potential modifications will be reduced. While it is impossible to quantify the changes in coal and oil generation that would result from this factor, it is likely that increases in generation from these units would primarily displace oil and gas generation.

7. The energy required for scrubber sludge extraction, preparation, and transport is equivalent to 4 billion kWh. This energy would probably be primarily in the form of petroleum products. Additionally, changes in coal transportation (as discussed in the next section) would result in some additional energy consumption.

The Nation's Coal Distribution System

The various legislative and regulatory proposals would mandate prescribed rollbacks of SO_2 of between 2.5 and 12 million tons per year. These rollbacks would be achieved by some combination of switching to lower-sulfur coal and scrubbing. If there is a substantial increase in compliance coal demand, the nation's coal transportation network which evolved to reflect current patterns of coal production and consumption will experience some strain and additional costs until the network adjusts to the new patterns.

To the extent that there is significant switching to lower-sulfur coal, there will be increases in western coal production, primarily in the Powder River Basin in Wyoming, in Montana, in Colorado, and also in central Appalachia--primarily eastern Kentucky and West Virginia. Each of these increases in coal production will have different impacts of the nation's coal distribution system.

With respect to increased western production, particularly in the Powder River Basin, all the increased production will be transported from the mine by rail, primarily by the Burlington Northern and the Chicago and North Western railroads. It is likely that there is ample capacity to haul these additional amounts of coal. Moreover, because of the increased rail competition out of the Powder River Basin due to the construction of the Chicago and North Western connector, rail rates will probably decrease, thus increasing the market reach and penetration of Powder River coals.

With respect to increased production in eastern Kentucky and West Virginia, the impacts on coal distribution will be more complex. Much of this increased production will move by rail, and the primary beneficiaries will be the CSX and the Norfolk Southern railroads. Most of the existing excess capacity of compliance coal is accessible to these two railroads. Conrail, on the other hand, has access to almost no reserves of compliance quality coal. Conrail will benefit only to the extent that it is able to encourage the development of compliance coal mines that it serves. Finally, barge traffic of low-sulfur coal should also increase. This traffic will generally move by truck, conveyor, or short-haul rail to the inland waterway system, and then by barge to powerplants sited on or near the river.

To the extent that scrubbing of higher-sulfur coal is the result of pending legislative and regulatory proposals, the impacts on coal distribution will be concentrated on those transportation modes or carriers that haul high-sulfur coal. However, the transportation and consumption of high-sulfur coal is more localized than the transportation and consumption of low-sulfur coal. For example, Illinois Basin powerplants often consume high-sulfur Illinois basin coal; Ohio powerplants consume high-sulfur Ohio coal; Pennsylvania powerplants consume high-sulfur Pennsylvania coal. Thus, there will probably not be major transportation impacts, or at least impacts of national significance, if the result of the current legislative and regulatory proposals is mandatory scrubbing.

Nation's Electricity Reliability

The capacity losses that could result from compliance with acid rain legislation could be as much as four percent of the nation's capacity. This four percent loss would include three components: premature retirements (three percent), capacity effectively lost to reduced reliability (.5 percent), and capacity required to provide power to operate scrubbers (.5 percent). Most of this loss would be concentrated in the Midwest, and specifically, the East Central Area Reliability Coordination Agreement (ECAR) comprising Ohio, Indiana, West Virginia, Kentucky, and portions of Michigan, Pennsylvania, and Maryland. Approximately 11 percent of ECAR's projected 1992 capacity could be lost due to compliance with HR3400, bringing ECAR's operating reserve margin down to 17 percent, even assuming completion of current construction projects on schedule.

Red Cavaney

STATEMENT FOR THE RECORD
ON
THE ACID RAIN PROVISIONS OF
S 768 - CLEAN AIR ACT AMENDMENTS OF 1983
ON BEHALF OF THE
AMERICAN PAPER INSTITUTE
AND THE
NATIONAL FOREST PRODUCTS ASSOCIATION
1619 MASSACHUSETTS AVENUE, N.W.
WASHINGTON, D.C.

FOR THE
COMMITTEE ON ENERGY AND NATURAL RESOURCES
OF THE
UNITED STATES SENATE
APRIL 30, 1984

I. Introduction

The following statement for the record is provided on behalf of the American Paper Institute and the National Forest Products Association (NFPA) for the Senate Energy and Natural Resources Committee hearings on acid rain control provisions of Amendments to the Clean Air Act. API/NFPA are national trade associations representing over 2,000 member companies which own and manage over 70 million acres of forest lands in the United States and manufacture approximately 90 percent of the nation's pulp, paper and solid wood products.

As part of our continuing evaluation of laws affecting the forest industry, API/NFPA have completed their most recent review of the Clean Air Act and proposed amendments, including those dealing with acid rain. As in the past, we fully support the goals of the Act. A decade of experience, during which the industry made capital expenditures in excess of three billion dollars to meet its requirements and achieve significant environmental improvements, including reductions in sulfur dioxide emissions, has provided us with valuable insight into many of the Act's provisions. Our hope is that various requirements of the Clean Air Act can be improved to produce positive environmental effects without imposing unjustifiable costs, uncertainties and complexities. To the extent the existing Act or proposed amendments do not meet this objective, industry will seek modifications. The following comments are submitted with that in mind. In addition, because the industry has devoted much of its effort on acid rain to analyzing its possible effects on trees and the role of forest litter in the natural acidification of soils, the following analysis of the causes and effects of acid rain will focus on forests.

II. The State of Scientific Knowledge on Causes and Effects of Acid Rain

The forest products industry depends on an abundant supply of healthy and productive trees for its raw material. In 1982, the industry converted this renewable resource into finished products valued at $120 billion. We, therefore, view with much concern reports of damage to forests that (a) could be attributed to emissions of oxides of sulfur and nitrogen and (b) could be stopped by reductions in those emissions. However, the lack of scientific consensus on possible damage to forests and other ecosystems, coupled with aberrations on what should have been the expected trends in deposition and effects, precludes the forest industry from supporting additional emission control proposals.

The industry has utilized the services of the National Council of the Paper Industry for Air and Stream Improvement (NCASI) to reach its conclusions on the effects of acidic depostion on forest productivity. NCASI has completed two reviews of the literature and ongoing research projects. The latter of these reviewed 179 literature references and 65 related research projects. The NCASI report, which is enclosed for the record, concludes,

> Probably the most important finding of this current review, and one which does not differ from observations made two years ago, is that as yet the evidence for damaging effects of acidic deposition on forest productivity has not been conclusively documented under field conditions.

A recent article by S. B. McLaughlin, D.C. West, and T. J. Blasing of the Oak Ridge National Laboratory supports this view. They state, "At present we have no proof that the most recently recognized component of present-day pollution regimes, acid precipitation, is adversely affecting forest productivity."

In addition, trends in acidic deposition and observed ecosytem effects raise important questions. The most compelling of these is the apparent role natural processes play in acidification. As related in testimony before the Senate Environment and Public Works Committee and the House Subcommittee on Health and the Environment by Dr. Ely Gonick, Senior Vice President-Technology for International Paper Company, many scientific papers report that acidification is largely the result of natural processes of decomposition of litter from the forest, that conifers are particularly strong acid formers and that as much as 90% of the acid in run-off from coniferious areas is natural in origin. The assumption that acid deposition significantly acidifies waters and harms trees is disputed throughout the scientific literature. For example:

- o In Western Douglas Fir areas where rainfall pH is 5.3 to 5.6, run-off pH is 4.0, indicating that even where rain contains little acid, the run-off can be very acidic.
- o The pH of litter under conifers in Maine will typically run 3.0 - 3.5 — representing an acidity ten times greater than the acid deposition in that region which averages about 4.3.
- o Meteorological data suggest that drought in the late 1950's, rather than acid rain, is a highly probable cause of the red spruce decline at Camel's Hump, according to Siccama and Johnson.

- Studies on the effect of soluble aluminum concentration on tree root mass do not show toxic effects until the concentration of aluminum exceeds 100 ppm. Dr. Ulrich, who studied the declining Solling forest, claims that acid rain makes aluminum soluble and the soluble aluminum is reponsible for tree root damage. The concentration of soluble aluminum under the conditions he cites has been calculated to be 2 ppm. Incidentally, the decline of red spruce is also attributed to aluminum by Professor Vogelmann.
- Many forest regions now are more acid than formerly, not because of acid deposition but because forests that were cut over or burned over, due to unchecked forest fires, are reverting to earlier vegetation patterns involving a more acid environment. Solubilization of aluminum in the Northeast is not recent either since pH of coniferous forests is low enough to solubilize aluminum even where acid rain is not involved. In fact, this solubilization is one of the ways that soil has been forming since the glaciation period of about 12,000 years ago.
- Data based on fossil studies in lake sediments show that some lakes in the Adirondacks were acidified 2,000 - 10,000 years ago when Fir and Hemlock moved into the area. In other words, acidity may be one of the "natural" cycles they go through.

International Paper Company, which owns approximately 1.1 million acres of land in Maine, made calculations based on forest data in the State on how the coniferous forest there might affect the pH of the waters. The Department of Agriculture provides detailed data on the forests there. Briefly:

- Maine has half the area of New England - over 33,000 square miles.
- 87% of Maine is forested.

- o 51% of the total forest is Spruce/Fir or 44% of the total land area of Maine.

International Paper sampled three different soils representing good, intermediate, and poor growing sites for conifers to analyze for pH and total acidity. Chart I summarizes the data. To simulate run-off they also determined the influence of humus and soil on the pH of water. In these cases, water of 4.2 and 5.6 pH was added to the humus/soil mixture and the pH measured. This was done at two additional levels of water, 10 grams and 50 grams of water per 2 grams of humus or soil. The results are shown on Chart II.

CHART I

pH of Humus & Soil Horizon (A)

Site	Humus	A Horizon
Good	3.2	3.1
Intermediate	3.1	3.0
Poor	2.6	3.6

CHART II

Acidification of water by a blend of 1g of humus and 1g of A Horizon soil to simulate run-off

	pH 4.2		pH 5.6	
	10 ml	50 ml	10 ml	50 ml
SITE				
Good	4.3	4.3	4.4	4.5
Intermediate	4.1	4.3	4.3	4.7
Poor	4.0	4.1	4.4	4.4

The acid content of an acre of humus + A Horizon on the good site totalled 5100 equivalents of hydrogen ion vs. only 100 equivalents per acre contributed by 40" of annual rainfall at pH 4.3.

Admittedly, these are limited data, but they give an order of magnitude picture of acid contained in natural conifer sources only vs. the contribution by acid rain. The data indicate that removal of acid due to acid rain would alter pH of Maine's waters by an insignificant amount. Does this amount of acid removal warrant a 4 billion dollar per year control program? Doubtful. Would it have any significant effect on the environment? Doubtful. In fact, the 1982 Annual Report of the National Acid Precipitation Assessment Program addressed to the President and Congress asked a series of questions and provided answers. The first question asked was, "Does acid deposition significantly affect aquatic resources, crops, soils, forests, materials, or human health?" It was answered by saying, "Except for poorly buffered lakes, evidence on other actual impacts is inconclusive. The National Program included intensive laboratory and field studies to develop a more definitive understanding of the potential for damage to sensitive resources"

A publication from the United States Geological Survey also conflicts with the assumed link between SO_2 emissions and pH levels of receiving water basins. In records collected over a 10-15 year period from the Hydrologic Bench-Mark Network, USGA found that stream basin pH followed no pattern with respect to increases and decreases in emissions of SO_2.

Furthermore, even if natural sources played no role in acidification and there was an apparent linear relationship between atmospheric SO_2 levels and stream pH, the National Academy of Sciences and others have found it impossible to decide which sources of emissions are responsible for the SO_2 loadings in particular receptor areas. These findings lead the forest products industry to a consensus view of serious reservations about the environmental benefit which would result from several of the acid rain control proposals now before Congress. Because of these reservations, we strongly support the research program recently outlined by Environmental Protection Agency Administrator William Ruckelshaus before several committees of Congress. The program is well-conceived and is directed at finding the answers to questions that should be resolved before any additional plan on acid rain can be developed.

III. Impact on Fuel Use Choices and Cost of Proposals

Notwithstanding the industry's general reservations over the potential for environmental improvements under S 768, legislation recently approved by the Senate Environment and Public Works Committee, we also have particular concerns with the following specific provisions of the Senate bill that may be of interest to this Committee.

First, the bill prohibits any increase in nitrogen oxide emissions from existing sources in the 31-state control region unless offsets are obtained. However, we are lacking strong scientific evidence on the role played by NO_x emissions in the acid rain phenomenon; there is no known effective conventional method for controlling existing sources of nitrogen oxide emissions; and offsets are not generally available. As a result, the bill likely would prevent any further conversions of boilers from gas and oil to coal, as well as preclude conversions to allow the sound practice of burning wood wastes alone or in combination with coal. This latter practice is employed in approximately one half on the new boilers recently added or under construction in the industry since 1978.

Second, the bill requires that all new emissions of sulfur dioxide in the control region be offset by reductions of emissions from existing sources. This provision would have a profoundly adverse effect on the full utilization of existing plant capacity and new industrial growth. This problem would be particularly acute in the South, where the relatively new industrial base and the historic dependence on gas and oil results in fewer opportunities for emissions offsets.

The forest products industry offers a case in point. Most of our recent and projected growth is represented by new sources of emissions in the South. Since 1980 (the base year for emissions off-setting in S 768), the paper industry has made over $2 billion in capital investments in the South. The $2 billion represents only that investment in new facilities or added capacity which results in new emissions. Each of these facilities would be forced to either (a) seek retroactive offsets, (b) retrofit new facilities which already meet stringent New Source Performance Standards, or (c) close down. The problem is intensified as additional new sources attempt to find offsets from a dwindling, if not non-existent, supply.

Third, the bill requires the greatest emissions reductions in five midwestern states which are currently hardest hit by economic conditions. Thus, it would place a heavy and inequitable economic burden on utility customers in those states whose econômies are least able to absorb these costs.

In addition, S 768 does not include a number of needed changes to existing law. By far the most serious omission, and one with a great impact on fuel use choices in the industry, is the failure to eliminate the percentage reduction requirement for industrial boilers. Section 111(a) of the Clean Air Act requires that as New Source Performance Standards (NSPS) are revised, coal users must reduce emissions from new boilers by a certain percentage regardless of the cleanliness of the fuel that is burned. This provision was enacted in 1977 to protect high sulfur coal producers serving electric utility companies who were expected to shift from high sulfur coal to low sulfur fuels as a means of complying with the Clean Air Act. While the Environmental Protection Agency has not yet decided the matter, the Agency may apply this requirement to industrial boilers as well when that NSPS is revised, possibly within the next several months.

The application of this requirement to industrial boilers seems to be particularly ill-advised, because most industrial boiler operators have already made the fuel use adjustments needed to comply with the current provisions of the Clean Air Act, and because coal produced for this use accounts for only ten percent of the total coal market.

In addition, mandatory installation of flue gas desulfurization (FGD) systems on industrial-sized boilers appears to be extraordinarily cost-ineffective. These costs are borne out by a study recently published by NCASI (the National Council of the Paper Industry for Air and Stream Improvement). The study was based upon data supplied by the consulting firm of Burns and McDonnell and utilized actual installed cost or detailed engineering estimates of FGD (scrubber) systems. The study, which is attached for the record, reached the following conclusions:

- Capital cost for scrubbers at industrial-sized (0 - 1,100 million Btu) boilers are significantly greater per unit of energy input than for utility-sized boilers. This difference becomes more pronounced the smaller the boiler.

- Actual capital costs of scrubber installation on industrial-sized boilers were two to three times higher than had been assumed in contractor work (Radian) extensively used by the Environmental Protection Agency in its cost estimate on SO_2 removal.

- In absolute as well as relative terms, the capital cost of installing scrubbers on industrial-sized (0 - 1,100 million Btu) boilers is more costly than had been envisioned.

Because virtually the same environmental gain could be achieved simply by burning cleaner, low sulfur fuels alone or in combination with wood, the forest products industry strongly supports exemption of industrial boilers from the percentage reduction requirements of the Clean Air Act. In the 97th Congress, the House Energy and Commerce Committee, strongly divided on most issues, approved such a provision by voice vote. The language adopted is provided for the Committee's review. It clarifies what we believe to be Congress' original intention on this matter.

REPEAL OF "PERCENTAGE REDUCTION" FOR INDUSTRIAL BOILERS (TAKEN FROM H.R. 5252 AS MODIFIED BY THE SWIFT AMENDMENT)

SEC. 103 (a) (1). Section 111 (a) (1) of the Clean Air Act is amended by inserting before "the percentage reduction achievable" the following: "(except as provided in paragraph (9)."

(2) Section 111 (a) of the Clean Air Act is amended by adding the following new paragraph at the end thereof:

> "(9) The provisions of subparagraph (A) (ii) of paragraph (1) respecting percentage reduction shall apply only to those categories of stationary sources to which such provisions apply under regulations in effect on December 31, 1981, except that such provisions (and any regulations adopted by the Administrator under such provisions) shall not require a percentage reduction in sulfur dioxide emissions for any cogeneration facility owned or operated by any person if --
>
> > "(A) the construction of electric power generation equipment for such facility is commenced after the date of the enactment of the Clean Air Act Reauthorization Amendments of 1982, and
> >
> > "(b) the maximum potential electric power output of such facility, together with all other cogeneration facilities owned or operated by the same person and located on the same or adjacent or contiguous property, does not exceed 125 megawatts.
>
> As used in this paragraph, the term 'cogeneration facility' has the meaning provided by section 3(18) of the Federal Power Act. The terms 'technological process' and 'technological system' as used in this section shall not be construed to require a percentage reduction in emissions from those facilities which are not required to achieve such a percentage reduction by reason of the preceding provisions of this paragraph."

(b) The regulations of the Administrator under subpart Da of part 60 of subchapter C of chapter 1 of title 40 of the Code of Federal Regulations shall, on the date of the enactment of this Act, cease to apply to the extent such regulations are inconsistent with the amendments made by subsection (a). The Administrator shall, promptly after the date of the enactment of this Act, amend such regulations to reflect the amendments made by subsection (a).

The increased costs of purchased electricity will impact the industry in a major way. The pulp and paper component alone of the forest products industry is third among industrial user groups of purchased electricity in this country. As a result, the industry will bear a significant portion of increased utility costs. It is difficult at this time to assign a dollar value to these increased costs and how they will vary from region to region. A recent analysis completed by Temple, Barker and Sloane, Inc., does project increases in industrial customer rates from 4 to 29 percent depending upon the state.

IV. Problems Associated With Premature Action

In recent testimony before the House Health and Environment Subcommittee, Administrator Ruckelshaus outlined some of the problems that could be associated with implementation of an acid rain control program before all of the facts are in. Specifically addressing the question of forest productivity, Mr. Ruckelshaus said,

> "This situation illustrates well why waiting for further research to be completed before initiating a control program is a rational decision. If, as many believe, sulfate deposition is not a major contributor to forest problems but oxidants or nitrates are, a significant reduction in SO_2 emissions could inadvertantly result in elevated levels of oxidants or nitrates. Our current understanding of atmospheric chemistry indicates that if we were to reduce SO_2, it might result in increased levels of oxidants. Additionally, excess oxidant could then combine with the NO_x to produce more nitrates. Thus, in either

case, controlling the wrong pollutant could conceivably make matters worse."

At the same hearing, Energy Secretary Donald Hodel pointed out that implementation of a program requiring significant reductions in SO_2 emissions at this time could lock in current scrubber technology, which produces tons of hard-to-dispose sludge and is costly and difficult to operate. Secretary Hodel pointed out that this result would be particularly troublesome since we are on the verge of proving alternative technologies which could more effectively control an entire range of pollutants.

V. Conclusion

In response to the Committee's request for the industry's views on specific matters, API/NFPA would offer the following observations:

- While major scientific advances are being made in the field, the scientific community is far from reaching a consensus on the causes and effects of acid rain.

- The Acid Precipitation Act of 1980, as enhanced by the President in his 1984 State of the Union Message, offers an excellent opportunity to reach some resolution to the important questions still unanswered. The industry is particularly pleased with the research plan outlined by EPA Administrator William Ruckelshaus in his recent appearances before Congress.

- It is the consensus of the forest products industry that current knowledge is not adequate to support further regulatory action of the magnitude represented by S 768 and other similar proposals currently before Congress.

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EXCERPTS

(THE APPENDICES ARE RETAINED IN THE COMMITTEE FILES)

ncasi technical bulletin

NATIONAL COUNCIL OF THE PAPER INDUSTRY FOR AIR AND STREAM IMPROVEMENT, INC., 260 MADISON AVENUE, NEW YORK, N.Y. 10016

ACIDIC DEPOSITION AND ITS EFFECTS ON FOREST PRODUCTIVITY - A REVIEW OF THE PRESENT STATE OF KNOWLEDGE, RESEARCH ACTIVITIES, AND INFORMATION NEEDS - SECOND PROGRESS REPORT

TECHNICAL BULLETIN NO. 392

JANUARY 1983

ncasi

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January 10, 1983

TECHNICAL BULLETIN NO. 392

ACIDIC DEPOSITION AND ITS EFFECTS ON FOREST PRODUCTIVITY - A REVIEW OF THE PRESENT STATE OF KNOWLEDGE, RESEARCH ACTIVITIES, AND INFORMATION NEEDS - SECOND PROGRESS REPORT

Both the cause and the effects of "acid rain", more appropriately defined as acidic deposition, continue to receive substantial attention. The acidic deposition phenomenon, first studied in an organized and intensive manner in Scandinavia during the past twenty years, has fostered a series of studies directed toward defining its possible causes and effects in other countries, including the United States. In the United States, acidic deposition serves as a focal point for consideration of legislation and regulation aimed at corrective action.

The scientific community remains in general agreement on the source of compounds responsible for the occurrence of acidic deposition, namely the sulfur oxides and/or nitrogen oxides formed during combustion in stationary and mobile sources. The relative importance of sulfur versus nitrogen oxides is not yet understood; therefore the specific benefits of a control strategy singularly aimed at either of the classes of compounds remains speculative.

The effects of acidic deposition in its three forms (dry deposition of gaseous materials, dry deposition as particulate, wet deposition), are currently less well understood than the cause. A growing body of evidence suggests that acidic deposition is contributing to the acidification of certain freshwater lakes in the Northeastern United States and Eastern Canada. The scientific question, which is of most concern to the forest products industry, is that of acidic deposition impacts on soils and the possible resultant effects on forest productivity. Acidic deposition may, on some soils (a) enhance the leaching of nutrients, (b) possibly alter the microflora and microfauna in the upper soil horizons, (c) induce elevated levels of aluminum activity in soil solution, and (d) directly hamper tree growth through mechanisms occurring as a result of direct contact.

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The attached technical bulletin consists of a review of the present state of knowledge, research activities and information needs with respect to acidic deposition and its effects on forest productivity. It is the second of a continuing series dealing with these subjects. It was prepared by Dr. Ivan J. Fernandez, NCASI Research Forester, who drew upon a wide and comprehensive array of national and international information resources for its development.

A total of 179 literature references are included in the review. Background information on 65 related research projects in the United States plus those in other countries is provided, and the acidic deposition networks around the world described. When compared to the review carried out two years ago, this represents a dramatic increase in information availability. This geometric growth is also reflected in the research funding on the effects of acidic deposition on forest productivity. Research programs identified in the United States which were in their infancy and funded at a level of $1.5 million annually in 1980 have now grown to an annual funding level of about $4.5 million. The total funding for acidic deposition research has grown in a like manner with expenditures of $14, $20, $26 and estimates of $35 and $37 million expected for the years 1980 through 1984, respectively.

The technical bulletin contents deal extensively with recent research findings on the direct and indirect effects of acidic deposition on forest vegetation. It also covers research on the effects of acidic deposition on forest soils and the evaluation of forest soil sensitivity to acidic deposition.

Acidic deposition monitoring to determine its composition and spatial and temporal distribution in the United States is described along with global monitoring networks as well. The forest products industry currently supports about 10 percent of the stations in the National Atmospheric Deposition Network. The elements of active institutional research programs which deal with the questions of acidic deposition and forest productivity around the world are identified.

Considering the extent and content of research currently underway and its expected information yield, outstanding information needs with respect to the effects of acidic deposition on forest productivity include (a) evaluation of forest soil sensitivity to acidic deposition, (b) determination of the quantity and quality of atmospheric contributions to the forest ecosystem through more extensive sampling of acidic deposition in commercial forest areas, (c) development of improved dry deposition measurement techniques for forested ecosystems, (d) investigation of critical forest ecosystem phenomena which have been identified as playing a major role in acidic deposition impact assessment, (e) identification and development of key forest management alternatives influenced by acidic deposition considerations, (f) evaluation of dendrochronology as an investigative approach to defining the relationship between acidic deposition and forest growth trends, (g) establishment of long-term investigations on forested ecosystems to assess acidic deposition impacts, and (h) development of analytical tools which can be used to assess the economic consequence of acidic deposition on forest productivity.

Of the identified outstanding information needs, particular attention is drawn to those specific ones which will require individual company initiative with regard to determining if acidic deposition is likely to affect the company owned forests. Among these are the (a) integration of specific measurements into soil mapping programs to determine soil sensitivity to acidic deposition and monitor any changes which occur with time, (b) improvement of the information base on ambient air quality and dry deposition, and (c) evaluation of the health status of company owned timberlands to quantify the possible occurence of changes for which no apparent causes can be identified.

Several important conclusions are drawn. Among these are identification of the most likely mechanisms by which direct or indirect effects of acidic deposition would influence forest productivity. Probably the most important finding of this current review, and one which does not differ from observations made two years ago, is that as yet the evidence for damaging effects of acidic deposition on forest productivity has not been conclusively documented under field conditions.

Your comments and questions on the contents of this technical bulletin should be directed to Dr. Fernandez or me at this office.

Yours very truly,

Russell O. Blosser

Russell O. Blosser
Technical Director

ROB:lb
Att.

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ACIDIC DEPOSITION AND ITS EFFECTS ON FOREST PRODUCTIVITY - A REVIEW OF THE PRESENT STATE OF KNOWLEDGE, RESEARCH ACTIVITIES, AND INFORMATION NEEDS - SECOND PROGRESS REPORT

I INTRODUCTION

A. General Overview

The deposition inputs of acidic materials from the atmosphere, popularly referred to as 'acid rain', to terrestrial and aquatic ecosystems is a phenomenon which has recently received international attention. Over the past ten years this area of environmental concern has been the impetus for an exponential increase in activity on the scientific, and political fronts.

The essence of the acidic deposition issue is that materials emitted into the atmosphere as a result of anthropogenic activities, principally the combustion of fossil fuels, are transformed into acidic substances and then returned in a wet or dry form to lakes, croplands, forests, and other natural communities. Wet deposition not influenced by these anthropogenic contributions would have a theoretically "normal" pH of approximately 5.6, or slightly acid. Recent studies suggest "normal" precipitation pH actually falls within a range from slightly below 5.0 to greater than 6.0 in natural environments. Extensive monitoring efforts in recent years clearly have demonstrated average wet deposition pH values range between 4.0 and 4.5 in the eastern United States and Canada. Similar levels of wet deposition acidity have been illustrated at various locations throughout the world. Concern over the impact of these atmospheric inputs on natural ecosystems has fueled the tremendous interest in this environmental topic.

In the United States, the geographic center for the debate on acidic deposition has been a corridor between the mid-west industrial region and the northeast. Evidence has shown some sensitive lakes in the northeast are exhibiting properties associated with damage from acidification. Although not clearly demonstrated, much of the acidic materials deposited in these areas is thought to be of anthropogenic origin primarily from mid-western utilities and industrial plants. These acidic substances, primarily SO_2 and NO_x, are thought to be transported along the prevailing cyclonic storm tracks which move west to east, while simultaneously being tranformed into sulfuric and nitric acids. Many scientists suspect that these acids are being deposited downwind on eastern states, resulting in the observed freshwater and potential terrestrial effects.

Acidic deposition is not a static factor in the environment, which makes research in this area as complex as any work dealing with natural ecosystems. Spatial variation exists between various geographic areas with respect to the form and degree of deposition acidity. It has been generally shown that dry deposition contributes a larger proportion of the total acidity than wet deposition when the receptor is closer to the source of emission. Dry deposition generally includes the gaseous forms of SO_2 and NO_x and dry aerosols. Frequently neither the popular nor scientific literature is clear on the composition and contribution of dry deposition, which makes proper interpretation of results difficult, if not impossible. With greater distance from the emitting source, wet deposition provides a greater amount of the total acid input. In the northeast, wet and dry deposition are thought to contribute roughly equivalent amounts of acidity to total deposition.

Temporal variation in deposition acidity has also been shown with intensity and duration of a precipitation event having a pronounced effect on the chemistry of the precipitation at any particular point in time. Precipitation events tend to have the lowest pH values at the beginning with gradually decreasing acidity as the event progresses. Areas which develop a snowpack during the winter months are unique in that acidic materials which accumulated in the snow cause an 'acid surge' during snow melt runoff in the spring. This 'acid surge' is characterized by a high level of acidity washed out of the snowpack by the initial increment of meltwater which can rapidly lower the pH of sensitive freshwater lakes and streams.

Research on the ecological effects of acidic deposition have focused on the areas of impacts on (a) freshwater ecosystems, (b) vegetation, and (c) soils. It appears now that the interaction between acidic deposition and soils plays a critical role in the ultimate impact of acidic inputs to streams, lakes, crop plants, and forest vegetation (1,2). For the effects on vegetation, investigators have distinguished direct effects of acidic deposition such as erosion of leaf surfaces, from indirect effects such as changes in nutrient availability from the soil. Most of the current concern for acidic deposition impacts on forest productivity has to do with the indirect effects on (a) tree nutrition, or (b) the effects of toxic elements mobilized in the soil.

(1) The Character of Forest Ecosystems - Before discussing the current research on acidic deposition and forests, several comments relevant to this subject should be mentioned. Forests can be generally characterized as acidifying ecosystems. Due to the composition of forest vegetation and the length of time for typical crop rotations, forest soils are often naturally acidic.

This property of forest soils is more pronounced under coniferous tree species and in regions which experience temperate climates. Indeed, many of the coniferous forests of New England and eastern Canada are supported by soil horizons of significantly greater acid character than ambient wet deposition.

Other forest perturbations have a significant impact on the nature of the dynamic chemical equilibrium which exists in these ecosystems. Variations in the patterns of land use, forest management practices, forest fires or pest outbreaks are examples of factors having significant effects on forest growth and the chemical status of soils and soil solutions. Given these considerations, it is imperative that one views the effect of acidic deposition on forest ecosystems as an increment to the myriad of other factors impacting on forest communities. The challenge for scientists working on this problem is to segregate the contribution from acidic deposition and contrast these effects with others operative in the ecosystem.

(2) The Forest Products Industry Viewpoint - The forest products industry has a need for up-to-date, factual information describing the relationship between acidic deposition and forest productivity. This industry is in the unique position of having resources on both the emitting (e.g. pulp and paper mills) and receiving (e.g. timberlands) ends of the acidic deposition debate, which clearly results in an objective approach to the problem of sorting out facts from speculation. Therefore, regulatory activity at the federal and state levels on this environmental issue has a significant impact on the forest products industry. There seems little doubt that the emission of SO_2 and NO_x from industrial facilities leads to transformations in the atmosphere which can increase the acidity of wet and dry deposition. Mobile sources of emission, primarily motor vehicles, also contribute significantly to the total NO_x produced. The question is whether further regulation of these emissions is warranted, and if so by how much, in the face of uncertainty regarding the ecological effects of acidic deposition. There are those who point out that rarely has environmental damage been legislatively averted based on proven cause and effect relationships, citing London fog and phosphates in the Great Lakes as examples (3). Others conclude that the present state of knowledge is inadequate for the establishment of meaningful air quality control standards (4), while some suggest that preliminary formulation of management and ameliorative strategies is warranted, but the lack of knowledge does not justify even consideration of management strategies to abate acid rain at this time (5).

(3) The National Initiative - In response to the clearly outlined need for research on this subject, a federally coordinated program has been developed to provide answers on the acidic deposition issue. This program was developed based on a document entitled "A National Program for Assessing the Problem of Atmospheric Deposition (Acid Rain)" prepared by the National Atmospheric Deposition Program (NADP) in 1978 for the President's Council on Environmental Quality. The national initiative on this issue has taken the form of a ten year program authorized by Title VII (The Acid Precipitation Act of 1980) of the Energy Security Act (PL 96-264) which was passed by Congress in June of 1980. This effort is now operational as a research program designed to address the causes and consequences of acidic deposition to provide a scientific basis for policy-making decisions. The level of effort for fiscal year 1982 was $18 million, with $22 million anticipated for 1983. The Interagency Task Force on Acid Precipitation (ITFAP) provides leadership at the federal level for setting program policy, overseeing its implementation, and providing administrative service for federally sponsored research and deposition monitoring efforts conducted by states, universities, industry, environmental organizations, and other groups in the United States, Canada, Mexico, and Europe. The "National Acid Precipitation Assessment Plan" was issued in final form during June 1982 by ITFAP, and provides the blueprints for the overall effort.

B. Scope and Purpose

The purpose of this technical bulletin is to provide the forest products industry with (a) a review of recent technical literature dealing with the effects of acidic deposition on forest growth, (b) a summary of current and planned research projects on this topic, and (c) an appraisal of information needs for the industry in regard to forest productivity and acidic deposition effects. Since 1981, NCASI has developed a program to address the information needs of the forest products industry with respect to acidic deposition. The material presented herein is designed to complement Atmospheric Quality Improvement Technical Bulletin No. 110 (January 1981), and provides an update on material specifically associated with forest productivity. It is intended that this technical bulletin will serve as a temporal marker for future updates on this subject. Many of the broad relationships discussed are supported by results from a number of investigations, and no attempt has been made to list all studies reporting results which may be supportive in these instances.

Acidic deposition is considered in this document to be atmospheric inputs of acids and acid precursors in the form of gases, aerosols or particles, and precipitation. Dry deposition includes gaseous inputs (i.e. primarily SO_2 and NO_x) and particles. Wet deposition includes rain, snow, sleet, hail, fog drip, and rime.

On the one hand, regulatory measures and the mechanisms which lead to ecological impacts may be very different for each of these intimately associated components of atmospheric pollution. On the other hand, this suite of atmospheric components are closely related with regard to source, transport, and total ecosystem response. Therefore, the ensuing discussions will include relevant research results on forest effects due to gaseous SO_2, particulates and heavy metals recently completed by scientists working on the acidic deposition question, while focusing on the available recent research dealing with acid precipitation impacts on forest productivity.

C. Forest Productivity Overview

A great deal of literature on acidic deposition has been generated in the past few years which discusses its effects on forest ecosystems. Much of the motivation for this literature stems from the sharp increase in public awareness and concern over acidic deposition coupled with the need for answers from research which have not yet been obtained. When a limited number of scientific investigations are repeatedly summarized and paraphrased it becomes extremely difficult for the casual reader to differentiate between demonstrated and potential effects of acidic deposition on natural ecosystems. Articles have appeared in the popular press, both in the United States and Europe, which suggest that wholesale destruction of our woodlands is now occurring due to acid rain (6,7).

As yet, evidence of direct damaging effects of acidic deposition on tree growth has not been documented under field conditions. This summation of the current state of knowledge is supported by a number of recent studies on this topic (1,8,9, 10,11,12,13,50). A recent report by the Comptroller General of the United States points out that the majority of negative impacts of acidic deposition on terrestrial ecosystems has been demonstrated in laboratory exposures to simulated acid rain (14).

The potential effects of acidic deposition on forest productivity are defined by the research which has been done on this subject to date. For readers interested in technical literature on the forest effects of acidic deposition, beyond the most recent material discussed in this bulletin, several publications are available as excellent source references (14, 15,16,17,18,156). From the body of scientific literature presently available, it appears certain generalizations can be made regarding acidic deposition and forest ecosystems.

The effects of acidic deposition on forest productivity can be either beneficial, neutral, or detrimental to tree growth. Since nitrogen (N) and sulfur (S) are the primary acidic components in acidic deposition and are also essential plant nutrients, an increased growth rate due to a fertilizer effect can result from acidic deposition. Forest sites where N or S are currently limiting growth, as is common for many forests with respect to N, may show improved yields due to these nutrient inputs.

With respect to detrimental impacts of acidic deposition on forests, the present knowledge suggests the mechanisms by which negative effects would most likely occur are (a) a loss of critical nutrient elements due to acidic deposition induced cation leaching or altered organic carbon processes, and (b) the toxic effects of elevated trace element levels such as aluminum (Al) levels in the soil solution. Specifically, the sulfate (SO_4^{2-}) and nitrate (NO_3^-) anions may induce the leaching loss of critical cationic plant nutrients such as calcium (Ca^{2+}), magnesium (Mg^{2+}), and potassium (K^+) due to the chemical requirement for maintenance of electroneutrality in soil solutions. Decreased rates of organic matter decomposition would tie up essential nutrients. Research also provides some evidence to suspect soil acidification may result in higher levels of toxic elements such as Al in soil solution which can damage tree root systems and impair normal moisture and nutrient absorption. A great deal of emphasis has been placed on these areas of concern in recent research priority evaluations.

II HISTORICAL NOTES

Historians point to past events as a treasury of information on which future decisions can be based. At the very least, some idea as to the historical development for a particular area of scientific inquiry allows the interested party to better define the perspective of new information. Dr. Ellis B. Cowling, Chairman of the National Atmospheric Deposition Program, recently wrote an excellent historical summary on the development of research on the acidic deposition subject (19). The following section highlights historical events from that summary which most directly bear on the forest productivity aspects of acidic deposition impact research.

An awareness of the basic processes involved in the acidic deposition phenomena is by no means a space age science. While several important observations regarding biological effects have been recorded, interpretation of these observations in light of source emission controls of varying degree among countries and an absence of reported ambient air quality, prohibits translation of these observations into a cause and effect relationship. This is particularly true in the United States, where ambient air quality standards have been a component of the air quality protection regulatory program for more than three decades. Work done in England during the 17th and 18th century provided basic concepts which are still valid today. In 1661 it was noted that industrial emissions influenced the health of biological organisms and suggestions were made for placing industries outside of towns and equipping them with taller chimneys. These workers also recognized the transboundary exchange of pollution between England and France. Hales noted in 1727 that dew and rain contain salts, sulphur, and other materials, stating the air is "...full of acid and sulphureous particles." From 1855 to 1856 Way completed a detailed analysis of English precipitation showing that nutrients in precipitation were valuable to crop production. Meanwhile, Linné in Sweden (1734) showed that a 500-year-old smelter near Falun, which caused the smell of sulfur, had corroded the earth so that no herbs could grow around it. Similar observations have been subsequently made in the United States and Canada prior to the advent of emission controls.

Since 1909, much of the literature on precipitation has used pH as a measure of acidity based on the development of the reference scale by Sørenson in Denmark. Crowther and Rostow, in 1911, demonstrated a gradient in precipitation acidity from a coal combustion center in Leeds, England and presented evidence of some inhibition for plant and soil processes. In 1919 the Austrian scientist Rusnor showed atmospheric deposition of acidic substances accelerated soil acidification.

The first detailed study of precipitation in the United States was published in 1923 by MacIntyre and Young. In 1939 Canadian researchers reported SO_2 emissions from a lead (Pb)-Zinc (Zn) smelter in Trail, British Columbia caused accelerated acidification and reductions in base saturation for soils.

The center of activity during the middle of this century was in the Scandinavian countries. Egnér and others were involved in the initiation of the first major precipitation chemistry network for Europe in 1948. The research of Tamm in Sweden between 1953 and 1958 clearly demonstrated the dependence of mosses and most forest plants on atmospheric sources of nutrients, especially N. Odén, another Swedish scientist, presented many of the postulated impacts of acidic deposition on water, vegetation, and soils as a result of his findings on precipitation acidity trends in Europe (1967, 1968). Bolin later drafted the Swedish Case Study for the United Nations Conference on the Human Environment in 1972 entitled "Air Pollution Across National Boundaries: The Impact on the Environment of Sulfur in Air and Precipitation" which noted damaging effects on materials and natural ecosystems.

During the period from 1972 to 1980 a tremendous growth in scientific activity occurred in relation to the acidic deposition issue. Workers in Sweden, Norway, Canada and the United States were active in research efforts which began to outline some observable and potential impacts that acidic deposition may have on forest ecosystems. Evidence showed increased heavy metals in forest soils, an experimental basis for declines in forest productivity, leaching losses from forest ecosystems, and accumulations of lead (Pb) and cadmium (Cd) in mushrooms, mosses, and other vegetation which then was transferred to foraging wildlife species. Also during this period the Norwegian program "Acid Precipitation - Effects on Forests and Fish" (SNSF Project) was conducted. Abrahamsen summarized the results of this major research effort by Norway in 1980, concluding that the fertilizer effects of acidic deposition, particularly of N, may offset detrimental effects for forests in that country. He also concluded that negative impacts for forests will most likely result from nutritional deficiencies or imbalances caused by acidic deposition.

A few dates during the 1970's should be highlighted, given the focus of this discussion. In 1974, Cogbill and Likens published maps for the eastern United States showing increased precipitation acidity between the periods 1955 to 1956 and 1972 to 1973. During that same year another United States scientist published research indicating artificial acid rain could accelerate the erosion of protective waxes on leaves, inhibit the nodulation in legumes, and alter host-pathogen interactions for plants. In Sweden (1976), Tyler showed heavy metals which accumulated in forest litter inhibited microbial processes and organic matter decomposition. In Norway (1977), Rosenqvist developed the general theory that natural soil processes controlled the acidification of both soils and waters, while Greszta in Austria (1978) showed forest soil accumulations of heavy metals lead to injury of young pine and spruce seedlings. Galloway and Whelpdale (1979) found that 95% of the atmospheric S in eastern North America was of anthropogenic origin and roughly 30% of these emissions would be deposited outside that region. In 1980, Ulrich demonstrated a significant correlation between Al in forest soils and a widespread growth decline in spruce, fir, and beech for German forests.

From 1979 to the present there has been an exponential growth in technical literature on this subject, and the reader is referred to documents previously suggested, NCASI Atmospheric Quality Improvement Technical Bulletin 110, and this bulletin for information on the most recent period of time.

III PRECIPITATION ACIDITY AND ACIDIC DEPOSITION

The following discussion is directed toward highlighting selected features of acidic atmospheric deposition phenomena. This area of meteorology has developed into an extremely active topic of research in light of the acidic deposition issue and would require a major allocation of resources to adequately review the literature on this subject alone.

For more extensive general discussions of atmopsheric acidity and emissions, transport, transformation, and deposition processes, recent publications are available (12,13).

Acidic deposition, popularly referred to as 'acid rain', deals with the phenomenon of atmospheric materials which have a greater acid character than is expected in theoretically non-polluted environments. The majority of atmospheric acidity is due to S and N compounds which are emitted into the atmosphere due to modern anthropogenic activities. Most of these inputs are thought to be in the form of SO_2 and NO_x (NO and NO_x). These chemicals are then oxidized in the atmosphere by heterogenous oxidation of dissolved gases in liquid aerosols and homogenous oxidation in the gas phase (3). A large number of substances, however, are involved in atmospheric chemistry which are considered to be acidic or potentially acidifying materials such as (13): (a) sulfur compounds and radicals - sulfur dioxide (SO_2), sulfur trioxide (SO_3^{3-}), hydrogen sulfide (H_2S), dimethyl sulfide [$(CH_3)_2S$], dimethyl disulfide [$(CH_3)_2S_2$], carbonyl sulfide (COS), carbon disulfide (CS_2), sulfate (SO_4^{2-}), sulfuric acid (H_2SO_4), methyl mercaptan (CH_3SH); (b) nitrogen compounds and radicals - nitric oxide (NO), dinitrogen oxide (N_2O), nitrogen dioxide (NO_2), nitrite (NO_2^-), nitrate (NO_3^-), nitric acid (HNO_3), ammonium (NH_4^+), ammonia (NH_3), and (c) chlorine compounds and radicals - chloride (Cl^-), hydrochloric acid (HCl).

Acidic deposition can be divided into wet and dry deposition. Wet deposition can be in the form of rain, snow, dew, fog, hail, rime or sleet, whereas dry deposition refers to gaseous or particulate atmospheric inputs. Theoretically, pure rainwater would have a pH of roughly 5.6 (2.5 µg/l H^+) as a result of a chemical equilibrium between pure water and atmospheric CO_2, which currently averages 0.03 percent of the ambient atmosphere. Much of the precipitation falling on eastern North America is currently well below this theoretical pH as can be seen in Figure 1; the mean precipitation pH data for this region falls between 4.0 and 4.6.

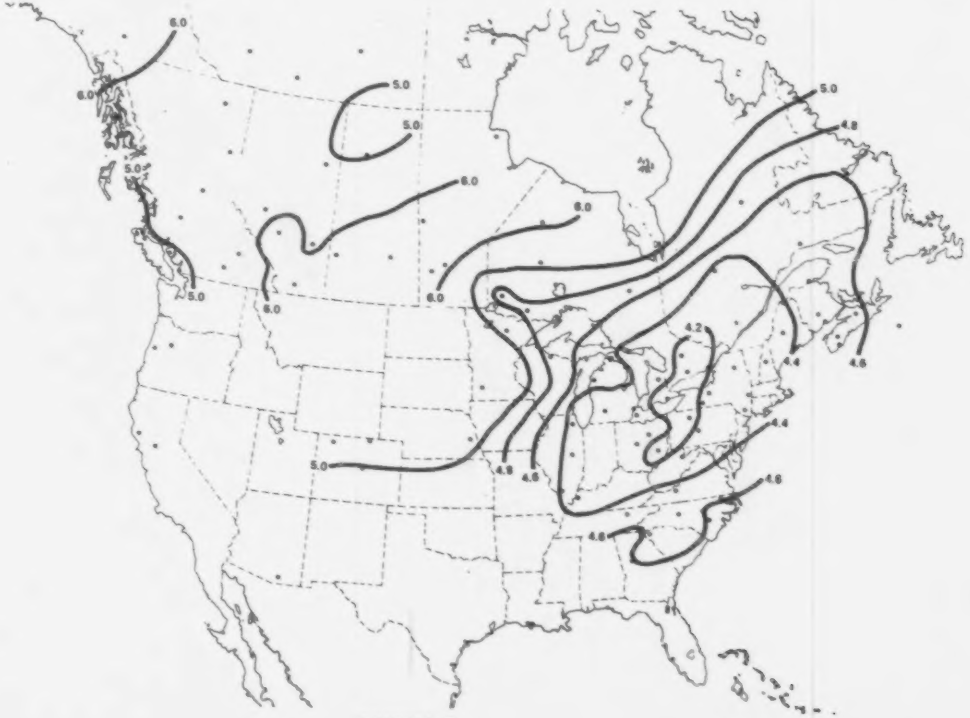

FIGURE 1.

MEAN ANNUAL pH OF PRECIPITATION IN THE UNITED STATES AND CANADA, 1979-1980. THE ISOPLETHS ARE BASED ON DATA FROM THE NATIONAL ATMOSPHERIC DEPOSITION PROGRAM (NADP) IN THE UNITED STATES AND CANADIAN NETWORK FOR SAMPLING PRECIPITATION (CANSAP) COLLECTED FROM APRIL 1979 THROUGH MARCH 1980. NADP DATA POINTS ARE AVERAGED FROM 16 OR MORE WEEKLY SAMPLES, AND CANSAP SITES OF 4 OR MORE MONTHLY SAMPLES WERE INCLUDED. SOURCE: W.W. KNAPP, DEPARTMENT OF AGRONOMY, CORNELL UNIVERSITY, ITHACA, NEW YORK, PERSONAL COMMUNICATION, 1981 (12)

Most of the acidity in acid precipitation is due to strong mineral acids (H_2SO_4 and HNO_3), which was shown by Lindberg *et al.* (20) to account for 70 percent of the acidity in precipitation at the Walker Branch Watershed in eastern Tennessee. A large proportion of the mineral acid component of precipitation is due to S compounds, primarily as a result of SO_2 emissions. Glass *et al.* (157) reported on New York and New England data which indicated 60 to 70 percent of the acid input was attributable to sulfuric acid, with only 30 to 40 percent associated with nitric acid.

The major sources of S are the burning of coal and petroleum products and ore smelting. Electric utilities currently contribute roughly two-thirds, and industry another one quarter of total anthropogenic SO_2 emissions. Industry has reduced these emission loads from 11 to 7 million tons in the last 20 years. Most of the NO_x emissions are associated with transportation (40 percent); however, the electric utilities and industry together supply an additional 55 percent of the total. The mix of S and N in precipitation does not appear to be static. In recent years the level of SO_2 emissions has declined; however, increases in NO_x emissions equal or greater in magnitude have occurred (21). Of the total S in the atmosphere of the northeastern United States, 90 percent is thought to be contributed by anthropogenic sources. Similar data on NO_x is not available. However, it has been estimated that 56 percent of the NO_x emissions in 1972 were from within the northeastern region, and nitrate increases in precipitation are reasonably well correlated to anthropogenic N emissions (4).

Dry deposition deals with the removal of gases and particulates from the atmosphere by processes not associated with precipitation. It is now believed that the dry deposition component of the total atmospheric input of acidity may be equal to, or greater than, wet deposition input in many cases. Evidence suggests that the dry deposition contribution to total acidity increases relative to the wet deposition component as one moves closer to point sources of emissions.

The mechanisms of wet and dry deposition can be categorized into five general processes. For wet deposition, S and N are removed from the atmosphere as (a) rainout, or (b) washout. Rainout is considered the transfer of materials to cloud droplets before they make their descent as a raindrop, while washout is considered the process of transferring materials to the falling raindrop. Rainout usually involves cloud condensation nuclei as aerosols of $(NH_4)_2SO_4$, $(H_4)_3H(SO_4)_2$, H_2SO_4, NH_4HSO_4, and NH_4NO_3. Washout mostly involves the solution of gaseous SO_2 and NO_x compounds. Dry deposition of acidic materials from the atmosphere occurs as a result of (a) surface absorption of gases, (b) particle sedimentation, and (c) impaction of aerosols on vegetation, soil, water or snow (22). For aerosols less than 0.1 μm in diameter, Brownian diffusion has the greatest limiting effect on particulate deposition rates. Sedimentation dominates the removal mechanisms of particles greater than 0.1 μm, and impaction is the most important process for particles with diameters near 0.1 μm (23).

Tanner et al. (24) have recently discussed some technical aspects of current understanding with respect to atmospheric aerosols and found that on the average, the acidity in aerosols is 10 percent or less of the molar amount of sufate in the sample. This is primarily due to the neutralization of sulfuric acid aerosols by ambient atmospheric ammonia. The data suggested atmospheric aerosols tend to be more acidic in rural regions versus urban centers, and there appears to be a diurnal flux, with acid aerosol levels lowest at night.

Not all scientists currently agree with the usual assumptions which are made with respect to atmospheric acidity. Sequeira (25) concluded that using a pH of 5.6 as an indication of 'normal' precipitation acidity may be a misleading approach. Various acidic and basic materials are also present in the atmosphere which he said can contribute to precipitation acidity. To illustrate, he pointed out that present levels of alkaline dust in United States precipitation are considerably lower than those between 1955 to 1956 and 1959 to 1963. Since it appears that the sulfate composition of precipitation has not increased over the last 20 years but acidity has, the increased acidity may be attributable to a decrease in the alkaline component of the atmosphere (i.e. Ca^{2+}). Gibson and Linthurst (26) recently discussed this relationship for the midwestern states, pointing out that SO_4^{2-} levels in the atmosphere were not correlated to precipitation pH for this region due to the high concentrations of Ca^{2+}, Mg^{2+}, and NH_3 from suspended dust (Ca^{2+} + Mg^{2+}) and natural plant and soil processes (NH_3).

Problems also exist in the ability to adequately measure deposition acidity, with currently available dry deposition monitoring techniques particularly poor in characterizing natural processes. Kerr (27) pointed out the ability to measure SO_2 absorption by lakes, moisture on vegetation, and by vegetation and soil are also weak, which becomes increasingly critical with proximity to emission source.

The quantity and quality of deposition is extremely variable with respect to location and time. Factors such as storm intensity, storm duration, season, precipitation form, and receptor properties all play critical roles in the quantity and quality of acidic deposition. Research showed that three Adirondack watersheds receiving equal quality precipitation on a temporal basis received significantly different total ion loadings. The largest basin received roughly 20 percent less total ion input (eq/ha/yr) on the average when compared to the other two basins. This study also found that pH measurements taken at the laboratory were usually higher than those taken in the field, which they attributed to NH_3 uptake (28).

Much of our current knowledge of atmospheric processes has arisen from statistical correlations between variables measured in the environment. Although it is possible to measure anthropogenic emissions reasonably well through direct methods or interpretation from fuel consumption data, an understanding of the natural emission processes for the various S and N compounds to accurately estimate the contributions from soil, water, and vegetation is likely. Although critical to calculating global element budgets, very little is known about natural sulfur emissions of marine, volcanic, and biospheric origin. Adams et al. (29,30) have recently reported research and theoretical considerations on the potential contribution of S from land surfaces which they feel significantly contribute to total global emission estimates.

Several interesting lines of investigation have been developed in relation to atmospheric phenomena and acidic deposition which should be mentioned. At the University of Rhode Island investigators have, for the first time reported the use in this country, of a trace element ratio between manganese and vanadium (Mn/V) as a signature for the origin and movement of air masses. Although subject to some controversy, this type of technique could provide valuable information on the source-sink relationship for atmospheric components in different regions (31). Also, research being conducted by General Motors suggested that reductions in NO_x to abate acidic deposition may cause serious problems in the attainment of ozone standards due to the chemical interaction of these substances in the atmosphere (32).

The overall theme which emerges from the literature indicates little doubt exists that SO_2 and NO_x are precursors to acidic deposition, and that anthropogenic emissions of these materials dominate total input. A great deal of disagreement exists on other related issues due to limited experimental results on extremely complex natural phenomena. Quantitative descriptions of (a) atmospheric transport, (b) definition of transformation processes, and (c) accurate determination of wet and dry deposition quality and quantity hold significant challenge for research in the atmospheric sciences. The evaluation of the effects of acidic deposition on forest ecosystems is, in itself, a difficult task. It will be imperative that better definition be provided in the future on ambient atmospheric deposition characteristics to allow more realistic experimental treatments and data interpretation in forestry research.

IV MODIFICATION OF ACIDIC DEPOSITION BY FOREST VEGETATION

Forests represent a complex type of terrestrial ecosystem and, due to the growth habit of the vegetative component, forests are often arbitrarily divided into "layers". A general description of the common forest layers would include (a) overstory vegetation, (b) understory vegetation, (c) ground cover, (d) forest floor, (e) mineral soil, and (f) bedrock. The overstory vegetation in a forest stand which has passed the stage of canopy closure acts as the first plane of interaction between acidic deposition and the terrestrial ecosystem. It has become apparent that the result of canopy interception with atmospheric materials has a significant impact on the nature of the deposition input to all subsequent ecosystem components. Students of forest influences have recognized for years the significant changes in quantity and distribution which forest canopies impart to precipitation through interception and evaporation. However, recent efforts in acidic deposition research have allowed a greater understanding of the significant qualitative changes which also occur in atmospheric deposition due to interactions with the forest canopy (28,33,34).

A. Qualitative Alterations in Deposition Due to Forest Canopy Interactions

Forest canopies generally cause a reduction in the total quantity of rain or snow which reaches the forest floor when compared to "open field" precipitation. High elevation forests, as discussed later, are often an exception to this statement. The reason for this phenomenon is due primarily to the evaporation or sublimation of rain, snow, and ice which is intercepted by the forest canopy. Abrahamsen (35) recently reported on a number of field plot experiments in Norway utilizing artificial rain treatments on lodgepole pine, Scots pine, and Norway spruce. Throughfall experiments from the Norway spruce plots showed that, of 50 mm of irrigation water applied by a rotating boom above the tree crowns, 9 mm were lost to drift, and only 61 percent of the remaining 41 mm applied reached the surface. The remainder was lost to interception.

Olsen *et al*. (36) examined the fluxes of water and chemicals in throughfall and stemflow of three subalpine balsam fir forests in New Hampshire with highly dissimilar stand structural characteristics. These authors list the structural characteristics of a stand which will affect the distribution, storage, and flow of water as being (a) stand density and bole diameter, (b) canopy density and height, (c) stand age, (d) species and foliage type, (e) seasonal absence of foliage, and canopy parameters such as (a) branching pattern, (b) bark texture, and (c) stage of foliage growth.

High altitude forests have been estimated to be in cloud cover 30 to 50 percent of the time. In the New Hampshire study, the capture of cloud droplets on canopy surfaces was found to actually increase the throughflow plus stemflow volume by 18 to 29 percent over incident precipitation. The greater the stand density, the greater the stemflow component. Stemflow was also more acid and, except for N, higher in chemical concentrations.

Similar results have been reported for upper elevation forests in Vermont which have been shown to receive 6 to 30 inches of precipitation per year as fog. Moisture resulting from cloud droplet condensation was close to five times more acidic than the ambient acid precipitation (37). The unique hydrologic properties of upper elevation forests are particularly noteworthy since these ecosystems are often targeted as being sensitive to acidic deposition impacts for a variety of ecological reasons.

Forest vegetation is also unique in its ability to act as a sink for dry deposits. The extremely large total surface area of forest vegetation canopies provide an enhanced opportunity for particulate and gaseous deposition. Uptake of gaseous pollutants such as SO_2 by trees occurs through (a) diffusion and (b) flowing air movement. Once tree foliage is in contact with gaseous pollutants, these substances may by (a) bound on exterior surfaces, (b) dissolved into moisture films on surfaces, and (c) taken up by stomata. Dissolution in moisture on the exterior vegetative surfaces is a particularly important process for gaseous SO_2 inputs due to its high solubility in water. Under conditions where dry deposition dominates, SO_2 can also be readily absorbed by leaves through stomata upon which rapid oxidation to SO_4^{2-} occurs in mesophyll cells (15).

B. Qualitative Alternations in Deposition Due to Forest Canopy Interactions

The atmospheric contribution of chemical substances to forest ecosystems has become a prime topic of investigation within the environmental field. A great deal of information on deposition chemistry is being accumulated by the various monitoring networks described in a later section of this bulletin. Most of these monitoring stations are carefully located to avoid any interference from overhead objects in order to provide representative samples of deposition under what is usually referred to as "open field" situations. In forested areas, the data from "open field" monitoring stations are intended to represent total input to the forest ecosystem, but research has shown that the chemistry of deposition inputs to the forest floor (i.e. throughfall and stemflow) are significantly altered by interaction with tree canopies. Indeed, chemical equilibrium in forest soils is regulated most directly by the composition of precipitation below the canopy rather than the characteristics and pH of open field precipitation samples.

Lee and Webber (38) recently published the results of their studies on model hardwood ecosystems treated with simulated H_2SO_4 acid rain. Seedlings of sugar maple and red alder were treated with artificial rain acidified to pH values of 5.7, 4.0, 3.5, and 3.0. Sampling and analysis was conducted on throughfall, litter leachate, and soil solutions at 20 and 100 cm depths. Overall, the hardwood canopy enriched the rainwater in Ca^{2+}, Mg^{2+}, K^+, Na^+, $SO_4{}^{2-}$, and raised the pH. The effect of this chemical enrichment was more pronounced with increased treatment acidity. The authors stressed the importance of evaluating the effects of acid precipitation on forest soils by studying these relationships in an ecosystem context.

Other investigations support the general trend of chemical precipitation enrichment by forest canopies. Work done on floodplain and upland forest communities in central Illinois by Peterson and Rolfe (39) showed canopy enrichment of precipitation for the elements K, Ca, N, Mg, and P. As would be expected, the composition of throughfall and stemflow was highly dependent on the presence or absence of foliage. Although the contribution of precipitation components in the return of nutrients to the forest floor is small compared to organic inputs from litterfall, these inputs are usually in ionic forms and readily available for root uptake. Major contributions of K^+ are possible via throughfall and stemflow due to the ease by which this cation can be leached from vegetation.

Bockheim (40) monitored precipitation, throughfall, stemflow, forest floor leachate, and leachate at the base of the rooting zone in stands of trembling aspen, sugar maple and red pine in Wisconsin. He found that the deciduous forest canopy was able to neutralize 57 percent of the incoming H^+ with the order of return for the various ionic species in throughfall being $K^+ > Ca^{2+} > Mg^{2+} > NH_4\text{-}N > H^+$ and $SO_4\text{-}S > NO_3\text{-}N > Cl^- > HCO_3{}^-$. Pine throughfall, however, contained 2.5 times the H^+ in precipitation with neutralization of the H+ load in these stands occurring totally in the forest floor and mineral soil. The order of return for the ionic species in the pine stand was $Ca^{2+} > K^+ > NH_4\text{-}N > Mg^{2+} > H^+$ and $NO_3\text{-}N > SO_4\text{-}S > Cl^- > HCO_3{}^-$. Throughfall and stemflow pH in the hardwood stand was 5.2 and 7.2, and in the pine stand was 3.9 and 5.3, respectively.

Skeffington (158) recently studied the pattern of soil pH surrounding trees at the Tillingbourne catchment in the United Kingdom. He chose oak, silver birch, and Scots pine trees growing at least 8 meters from the nearest neighbor tree and groundcover consisted of bracken fern. Soil pH increased with distance from the bole, with pine having a more acidifying effect than birch, while oak had the least impact. No relationship between soil pH and compass direction was detected. He suggested three possible mechanisms to explain the acidification of soil by trees: (a) tree uptake of cations in excess of anions causing H^+ release, (b) the production of acidic litter by trees, and (c) the effective filtering of aerosols and gaseous pollutants by forest canopies.

Work done on the Walker Branch Watershed, a hardwood catchment in eastern Tennessee, showed that total acidity in incident rain was unchanged by canopy interaction (20). There was a major shift in the composition of total acidity between incident rain and throughfall, with the contribution from strong acids decreasing from 70 to roughly 45 percent, respectively. These authors stressed the importance of assessing the data in light of the specific condition and interactions which produced them.

For example, a light rain, actually contributing a small chemical input to the canopy, which follows a dry climatic period, may not wash off leaf surfaces. The moisture would contact previously dry deposited substances leading to a concentration, in solution, of toxic materials by several orders of magnitude. This condition would greatly enhance the potential for physiological damage which would continue to increase upon droplet evaporation. An accurate understanding of the relationship between physiological effects and precipitation characteristics under these circumstances would demand a consideration of the specific climatic conditions under which interactions had occurred.

C. German Studies on Beech and Spruce

A great deal of research has been conducted on the beech and spruce forest types in Germany in relation to the acidic deposition question. These forest types, prevalent in central Europe, have been shown to have a tremendous capacity for filtering out aerosols from the atmosphere. In some cases trees reduced the aerosol particle content of the atmosphere below the canopies to 60 percent of that found above the canopies, with spruce showing a greater efficiency than beech (41,42). The minimum capacity for filtering was shown to be for particles between 0.3 to 0.7 μm in diameter. Deposition velocities for particles ranged from 0.3 to 2.5 cm/s with minimum values for mass-mean-diameters of approximately 1.0 (43).

Dry deposition in canopies was much larger for spruce than beech, particularly during winter months. Spruce averaged 150 percent greater aerosol deposition (Na^+, Ca^{2+}, Mg^{2+}, Cl^-) and considerably greater deposition of H^+ and $SO_4{}^{2-}$ than beech. The higher level of H^+ and $SO_4{}^{2-}$ was thought to be due to the absorption of SO_2, and its subsequent oxidation by water films on needles and bark surfaces throughout the winter. Much of the chemical enrichment in throughfall composition was attributed to the washing off of deposited aerosol particles (44,45, 46).

D. Further Considerations

More work is needed in quantifying and evaluating the effects of forest canopies on the character of acidic deposition in forest ecosystems. New approaches to the problem could entail artificial deposition collectors which more realistically simulate tree foliage. DeCatanzaro and Binkley (47) recently used atificial Douglas-fir foliage attached to precipitation collectors and found 6 to 8 percent more water and 23 to 143 percent more Ca^{2+}, K^+, $NH_4{}^+$, $NO_3{}^-$, and $SO_4{}^{2-}$ were collected than by collectors without artificial foliage.

The implications for forest management of canopy effects on deposition will also need to be examined. Simmons (48), for example, recently suggested that the "forever wild" policy of the Adirondack Park in New York has elevated the acid rain problems in this region to a critical status. His reasoning is based, in part, on the idea that managed stands have less stem per acre of sun-loving, shade intolerant species due to intermediate cuttings. Thus, more precipitation is allowed to reach the forest floor than in an unmanaged stand. This would reduce total acidic inputs due to less foliage absorbed SO_2 and dry deposited materials being added to the ecosystem as throughfall and stemflow.

Clearly a great deal of research is needed to allow accurate assessment of the impacts of canopy-induced alterations on deposition. It is generally understood how forest canopies provide a complex surface for the physical interception of atmospheric substances. The result is a redistribution of precipitation into the evaporative loss, throughfall, and stemflow components of the hydrologic cycle. The forest overstory also provides an extremely complex and extensive physical receptor for dry deposition processes.

Although the unknown chemical mechanisms associated with forest canopy-acidic deposition interactions may offer the greatest challenge to research in this area, certain relationships which occur have been revealed by numerous studies (49).

It appears that the chemical alteration of precipitation by tree crowns is due to (a) the washing and leaching of surface deposits, (b) absorbed deposits, and (c) excreted metabolites. The amount of chemical leaching of foliar substances which occurs is a function of the (a) frequency, (b) duration, and (c) intensity of precipitation. Studies in both Europe and North America have repeatedly shown a marked ability for forest canopies to filter substances from the atmosphere.

A significant difference between the effects of coniferous and deciduous species is apparent in throughfall and stemflow chemistry. Coniferous forests foster a higher acidity in throughfall solutions under natural conditions whereas deciduous species have demonstrated a marked ability to buffer acidic inputs. The acidifying effect of coniferous foliage versus deciduous foliage is thought to be the result of (a) lower base content of coniferous foliage, (b) a greater production of organic acids, and (c) a greater ability for the accumulation of dry deposited acid materials, particularly due to the year-round retention of foliage. Although the trends are clear, specific information will be required to quantify these relationships. Meaningful evaluations of the relationship between chemistry and soil or water effects in forested ecosystems demands accurate interpretations of intermediate canopy interactions. From the practical viewpoint, watershed managers and silviculturists will want to know how alterations in stand characteristics will effect chemical equilibrium in the ecosystem.

V RECENT RESEARCH: DIRECT EFFECTS OF ACIDIC DEPOSITION ON FOREST VEGETATION

A. General Comments

The separation of acidic deposition effects on forests into categories is, at best, an arbitrary distinction used to facilitate the discussion of research on this topic. As with most biological systems, any one aspect of forest ecosystem reaction to acid inputs is intimately associated with all other system components. Likewise, the context of a discussion is important for the clarity of biological terminology. Separation of vegetable from mineral components is clear when one discusses tree leaves and groundwater, but extremely indistinct when one studies root rhizosphere biogeochemistry.

With these thoughts in mind, the following discussion of acidic deposition effects on forest ecosystems has been divided so as to facilitate a consideration of recently reported research. As Hornbeck (159) emphasized, the foresters role on the acidic deposition issue is primarily one of "staying aware" of the results of scientific inquiries. He also pointed out that the effects of acidic deposition on forests will be extremely difficult to quantify because (a) methods for measuring forest productivity over large areas are not sensitive enough, and (b) damage to forests by insects and disease can mask any acidic deposition impacts.

Indeed, it has already been stated that as yet, unequivocal evidence for direct, damaging effects of acidic deposition on forest trees has not been obtained under ambient conditions. The publications discussed below are recent studies related to this subject.

B. Tissue Injury from Acidic Deposition

The most obvious result one might expect as a consequence of applying acids to vegetation is a physical change in the tissue and possible cellular necrosis. In a discussion of the experimental results currently available, Evans (51) suggested the initial effects of acid precipitation would be seen on organisms inhabiting leaf surfaces and on epidermal cells. With increasing duration and frequency of exposure to acid precipitation, the internal leaf cells would begin to show treatment effects. The differences between plant species in their response to acid precipitation effects on vegetation appear to be primarily a function of the degree of leaf wetting and differences in cellular responses to low pH rain.

One of the few studies completed to date on the evaluation of foliar thresholds to acid precipitation damage for forest species was reported by Haines _et al_. (52). In these experiments, seven angiosperm and one gymnosperm species from the Coweeta Hydrologic Laboratory were subjected to artificial acid rain with pH values of 2.5, 2.0, 1.5, and 0.5. The tree species included in this study were seedlings of white pine, black locust, chestnut oak, hickory, yellow birch, red maple, and flowering dogwood. The application of treatments between pH 1.5 and 0.5 produced necrotic spots for all species, while treatments of pH 2.5 rarely induced necrosis. Pine showed the greatest resistance to damage with a threshold for necrosis between pH 1.0 to 0.5, with all other species exhibiting thresholds between 2.5 and 2.0. These authors stated that developing foliage seems more susceptible to damage than mature tissue. One important point brought out in this article is that although mean precipitation pH is well above these threshold values, single low pH precipitation events may be the critical factor in determining overall precipitation damage.

Ulrich (85) described the symptoms of acid deposition injury in German forests evident since the spring of 1980. He stated green leaves of beech and fresh shoots in spruce and oak are discarded throughout the vegetative period and found on the ground. The break-off point is brown, indicating leaf or bud tissue damage, and scars from missing leaves or shoots, with associated bark damage, are evident in the upper crown region. Spruce needles show yellow discoloration, browning at advanced stages, and needle loss. While these symptoms are considered mainly due to indirect effects of acidic deposition, direct impacts of gaseous air pollutants on vegetative tissues may also play a role.

Percy and Riding (53,54) have studied the effects of acidic air pollutants on white pine in both seedling and field studies. In their experiments using two year old white pine seedlings, exposure to air containing 132 µg SO_2/m^3 produced significant biochemical alterations. Most of the cellular injury was restricted to the mesophyll parenchyma, a logical result, since stomatal openings allow direct contact between gases and mesophyll tissue. They classified these effects as "latent" or "hidden" and suggested SO_2 impacts could contribute to a reduction in growth by successive increments. It should be noted that these are high levels of SO_2 for non-urban forests in general. These workers also had previously completed a histological study of white pine needles from trees growing (a) within 1 km of four sulfate-process pulp mills (emitting sulfur dioxide, hydrogen sulfide, chlorine, particulates, and aerosol black liquor contaminants), (b) within 50 to 100 m from major highways, and (c) in areas remote from anthropogenic inputs. They found evidence of fragmentation and structural degradation in the epicuticular waxes on needles to be evident near the highway and pronounced near the pulp mills.

Steiner and Karnosky (55) examined the effect of Provenance on the reaction of two species of ash (Fraxinus americana and F. pennsylvanica) to 1.0 ppm SO_2 levels. Using twenty-six different provenances in total, seedlings were exposed to these SO_2 levels, which were in combination with 0.5 ppm O_3, for periods of 7.5 hours. Damage by SO_2 was characterized as bifacial, interveinal, tan, necrotic areas on older and middle-aged leaves. Family-within-provenance differences (provenance is the geographic area and environment to which the genetic constitution of parent trees for a species have adapted), in response to treatments of both O_3 and SO_2 were significant. Combined provenance and family effects accounted for 16 to 28 percent of the total variation in seedling response to SO_2. Variation among provenances was greater than variation within provenances for O_3, but the opposite was true for SO_2. Provenance means varied with geographic origin.

Fowler et al. (160) examined the degradation of epicuticular wax on Scots pine needles from polluted and non-polluted sites in a field study which indicated degraded wax structure during the first eight months of needle expansion at polluted sites. Differences in wax quantity between sites was not large, with the authors concluding changes in wax form, as observed by electron microscopy, were the major effects.

Recently published proceedings from a symposium on air pollutants in northern climates (161) offered an excellent collection of papers on analytical techniques and research results for high atmospheric pollution area impacts to forest vegetation, particularly with respect to SO_2, NO_x, and heavy metals.

C. Disrupted Physiological Processes from Acidic Deposition

Beyond a physical alteration of the vegetative tissue, the next level of concern would be on the biochemical consequences to foliar processes resulting from acidic air pollutants. The present knowledge on this level of plant processes is much less sophisticated for forest species than for the economically important agronomic crops. Although still not as well understood as agronomic information on acidic deposition effects, considerably more attention has recently been focused on studying the physiological responses for forest species.

Reporting on as yet unpublished research, Rice et al. (56) recently discussed their findings on "basal injury syndrome" in conifers. Damage, previously thought to be due to Matsuccocus scales, is manifested as lesions occurring in needle tissue at the perimeter and under the fasicular sheath covering the base of the needle bundles in conifers. These investigators have found that pathogen infestation is a secondary invasion after abiotic agents have previously caused damage. They suggest that acidic, gaseous pollutants and particulates are dry deposited on needle surfaces, then dissolve in raindrops, which upon evaporation draw the pollutants under the fasicular sheath. These materials are concentrated by subsequent wetting and drying cycles with cellular damage progressing as cell enlargement (hypertrophy), excessive multiplication (hyperplasia), death (necrosis), and callus formation.

Sandhu et al. (57) cite research which indicates that hybrids of pine in the field exposed to elevated SO_2 levels initiated photosynthesis later in the spring and had a lower maximum photosynthetic rate than non-exposed trees. These writers also suggested that epiphytic lichens and bryophytes may be valuable bioindicators of air pollutants, since they occupy a niche dependent on air-borne materials essentially independent of the forest soil, and are considered to be extremely sensitive to air pollution.

Smith (15) discussed the recent work done on the suppression of photosynthesis by various air pollutants including SO_2 and heavy metal species. Although clear evidence exists for potential impacts of acidic air pollutants on the photosynthetic capability of forest species, the author stressed the lack of research on large trees in natural environments.

Smith also outlined the potential points of interaction between air pollutants and sexual reproduction of forest trees as being (a) pollen production, (b) pollination, (c) fertilization, (d) fruit and seed set, (e) seed germination, (f) seedling development, (g) juvenile development, and (h) flower and cone initiation. Although the research on these stages is limited, some experimental evidence exists for acidic deposition effects on germination and tube elongation along with reduced seed germination resulting from heavy metals in the forest floor.

Cox (58) studied in vitro pollen assays for a variety of forest species in response to simulated acid rain treatments. The results indicated that pollen germination was stimulated (trembling aspen) and pollen tube elongation was stimulated (red pine) with acid treatment. He pointed out fertilization efficiency could be affected by altering the timing of physiological events such that the pollen tube may reach a non-receptive stigma or ovule. The broadleaved species studied (paper birch, trembling aspen, and sugar maple) were sensitive to pH values in a range less than 3.0 to 3.6 with respect to significant reductions in germination. White pine and hemlock were considered the most sensitive coniferous species. Treatment effects were attributed to the hydrogen ion and not to the associated anion.

Raynal et al. (59,60) recently published the results of a series of studies on acid precipitation effects on seeds and seedlings of forest trees. Seeds of sugar maple, yellow birch, eastern hemlock, red maple, and white pine were exposed to treatment pH's of 3.0, 4.0, and 5.6. A wide variation in sensitivity to germination effects existed between species. Yellow birch and red maple, but not sugar maple, showed germination inhibition at pH 3.0. Among the conifers, hemlock showed no treatment effects, but the acidic substrate stimulated germination in white pine. They pointed out extrapolation of these types of laboratory results to field conditions is dangerous due to the ability of the forest floor to strongly buffer the seed microenvironment.

These workers continued this line of investigation further on sugar maple seedlings treated with artificial acid rain containing nutrients (0.1 Hoagland's solution) or acidified artificial throughfall solutions. Whereas sugar maple seed germination was not affected in the first experiments, these studies showed radical elongation reduction at pH 3.0 or less. Seedling growth was shown to be a function of soil fertility with increased growth in the absence of added nutrients at pH 3.0, even with some foliar damage evident. Decreased growth in the presence of high fertility levels only occurred when acidity was increased to a pH of 2.0. This type of response may be important to sugar maple, since seedlings have been shown to germinate early under the snowpack and may be subjected to highly acidic snowpack meltwaters.

Other members of the forest ecosystem may be affected by acidific deposition. Although not of direct importance to overall forest productivity, lichens play a key role in the early establishment of vegetational successions on harsh substrates. Lechowicz (61) found the caribou lichen, Cladina stellaris, exhibited impaired photosynthetic capabilities when wetted with pH 4.0 artificial acid precipitation. The maximal photosynthetic capacity of these species was reduced by 27 percent with a 14 percent delay in attaining this reduced photosytnthetic rate after rewetting.

D. Added Nutrients from Acidic Deposition

Valuable insight into tree nutrition consequences of acidic deposition could be gained by identifying the source to elements in tissue. This is at present a largely unexplored area of research. Most commonly, plant nutrients are thought to be supplied to above-ground tissue after root absorption and translocation. Many of the chemical components in acidic deposition, including the abundant N and S, are essential plant nutrients. If these substances are deposited directly on aerial tree organs in an available form, or can be transformed into an available form, the direct addition of nutrients to foliage from acidic deposition is possible. Nutrient budgets for forested ecosystems can indicate the source of a tree nutrient as being from atmospheric deposition, but determining whether uptake was direct or mediated by the soil is difficult.

Clearly the major chemical elements which dominate the effects of deposition acidity are S and N, both of which are nutrients essential for plant growth, and both of which are supplied to some extent by atmospheric deposition (62,63).

There is very little information on atmospheric sources of nutrients when compared to the knowledge of soil supplies, and much more is known about agricultural plant requirements. Tabatabai et al. (64) recently pooled data on deposition chemistry for Indiana, Iowa, Michigan, Minnesota, Nebraska, Ohio, South Dakota, and Wisconsin, concluding "......current levels of N, S, and P (especially S) in precipitation in this region are beneficial to agricultural production. This is especially true for agricultural and grassland ecosystems that receive little or no fertilizers."

For forested ecosystems, Abrahamsen (1,65) concluded acid precipitation effects on growth were primarily a nutrition problem. Most of the growth effects on forests he attributed to soil conditions resulting from (a) positive growth effects on high SO_4^{2-} adsorbing soils deficient in N or S, (b) no growth effects on high SO_4^{2-} adsorbing soils deficient in other macronutrients, or (c) long-term negative effects on low SO_4^{2-} adsorbing soils. The N supply in temperate forest ecosystems was considered a key limiting factor to growth, since most of the N supplied through atmospheric deposition is retained within the ecosystem. These nutrient additions provide significant contributions to the total N budget of the ecosystem (46,49).

Johnson et al. (49) pointed out that S deficiencies have been indicated in forests which are remote from pollution sources such as the northwestern United States and eastern Australia. They stated that a deficiency in S may not directly reduce growth, but may cause an accumulation of non-sulphur containing amino acids, which increases the susceptibility of trees to foliar attack by fungi. Therefore additions of atmospheric S to these stands could both improve growth and tree form.

One aspect of precipitation deposited nutrient additions usually not taken into account was brought out by Evans et al. (4). They questioned whether nutrients added by acid precipitation could stimulate productivity directly, since surfactants are usually used to increase foliar penetration in agricultural research using foliar fertilization. Without such additions, significantly slower rates of penetration, and therefore uptake, are to be expected.

Gaseous uptake of acidic materials may also be a factor in nutrient additions. In a recent presentation, Keller (66) pointed out that S from atmospheric SO_2 can be used to satisfy some of the requirements for this nutrient by tree species.

Reporting on fumigation studies utilizing "realistic" SO_2 concentrations and forest species in closed chambers, he concluded six factors controlled S content of foliage. He considered external factors to be (a) concentration and duration of fumigation, and (b)climate (wind velocity, etc.), with internal factors being (c) species and genotype, (d) root-uptake of water and nutrients, (e) translocation and physiological activity, and (f) detoxification.

E. Concluding Comments

Without evidence presently available directly linking acidic deposition to adverse forest effects, the value of current research on this topic lies in determining what potential consequences of deposition inputs exist and their probability of being manifest in forest productivity. Information on standards for air quality currently needed to protect forest ecosystems is clearly not available (4). Generalizations can be made as far as threshold levels for tree damage, but these provide little information to allow the interpretation of forest productivity effects in specific situations. An international conference on acid deposition in Sweden concluded tree growth may be decreased when mean annual SO_2 concentrations were as small as 25 to 50 $\mu g\ SO_2\ m^{-3}$, which would include episodes of 100 to 200 $\mu g\ SO_2\ m^{-3}$. Foliar damage to forest trees seems to occur, based primarily on research conducted under artificial conditions, when precipitation pH is 3.0 or below (65). Information, based on well designed research, is urgently needed to describe dose-response relationships in forest species for acidic deposition effects.

VI RECENT RESEARCH: INDIRECT EFFECTS OF ACIDIC DEPOSITION ON FOREST VEGETATION

For the purpose of organization, the following discussion of recently reported investigations on the indirect effects of acidic deposition will focus on studies not previously discussed and not considered in a subsequent section on forest soils. Without question, alterations in tree growth which result from the impact of acidic deposition to forest soils *is* an indirect impact on forest productivity. The volume of literature on forest soil aspects alone warrants separate consideration, and is therefore treated in a subsequent section.

A. Leaching of Vegetative Tissue

When acid precipitation comes into direct contact with tree foliage there exists an opportunity for leaching of materials out of these tissues (16). Much of the research discussed in the previous section on vegetative modification of acidic deposition is pertinent to the present topic. It is clear from the literature that the interaction of the crowns with precipitation results in the chemical enrichment of these solutions (28,38). Several processes are involved in this chemical enrichment which includes both leaching and the washing off of previously deposited materials.

Although investigations are being carried out to clarify this subject, very little information is currently available. Clearly, both inorganic and organic substances can be leached from plant tissues (162). The mechanism by which this occurs is by leaching or ion exchange of materials from tissue, and represents a part of the internal cycling of elements, not a nutrient input. Lakhani and Miller (67) referred to this phenomenon as "crown leaching" and discussed some approaches to its investigation.

Of the ionic species most prevalent in throughfall and stemflow, the K^+ ion has the greatest potential for being derived from crown leaching processes, due to its ionic character in the cell sap of plant tissues. Some evidence exists to show that most elements, except Cl^-, are more resistant to removal from softwood than hardwood canopies. It is thought that the thicker cuticle and reduced surface to volume ratio of softwood species contributes to this effect (36).

The state of knowledge on this topic might best be expressed by Smith (15) who stated, "The data reviewed to support the hypothesis that acid precipitation accelerates leaching loss of nutrients from forest foliage are not convincing. The limited analyses of throughfall in natural environments have not adequately differentiated material actually leached from the plants from material deposited on and subsequently washed from the foliage."

B. Effects on Symbiotic Organisms

One of the unique properties of forest canopies is their complexity as a compartment within the forest community. In forest canopies, particularly for softwoods, extensive populations of epiphytic lichen cover canopy surfaces. Olsen *et al.* (36) showed that NH_4^+ and NO_3^- were the only chemicals which had a lower concentration in stemflow than throughfall for fir canopies. They attributed this to the greater exposure of stemflow to epiphytic lichens which have a marked ability to take up inorganic N compounds. They pointed out that concurrent with inorganic N assimilation by these organisms is the release of organic N in particulate and dissolved form. Epiphytic bacteria also can contribute to this process.

Shriner (68) discussed the potential impact of acidic deposition on phylloplane-inhabiting nitrogen-fixing bacteria and lichens in forest canopies. Citing evidence on research with epiphytic lichens in Douglas-fir canopies, it appears a threshold for precipitation between pH 4 and pH 2 exists whereby N_2-fixation rates are reduced for these organisms.

Research in Canada has shown epiphytic lichens to be extremely sensitive to pollutants, including acid precipitation. Robitaille (69) reported observations of epiphytic lichens in a forest near an SO_2 emission source, and in a control area. Lichen exposed to the acid pollutant site had decreased thalli pH and increased Cu, Pb, and Zn in the downwind direction. The disappearance of epiphytic communities in acid polluted sites was considered to have resulted from (a) SO_2 and its pH-dependent toxic derivatives, (b) metals, and (c) acid precipitation. Sandhu *et al*. (57) suggested using these air pollution sensitive organisms for developing a map of pollution distribution by recording lichen species and density distributions.

C. Plant Stress Susceptibility

Trees in natural environments are continuously exposed to a variety of environmental stress factors which limit forest productivity. A possible consequence of acidic deposition on trees could be an alteration of their sensitivity to other air pollutants, plant pathogens, or essential growth factors. For example, foliage which has been exposed to acid precipitation may be more subject to wilting or water stress (4). Johnson *et al*. (163) found some statistical relationships suggesting drought stress in several pine species is exacerbated by acid environmental conditions.

Shriner and Cowling (70) discussed the effects of acidic deposition on plant pathogens. They concluded that plant pathogenic fungal spores and bacteria were extremely vulnerable to acidic deposition effects during the processes of dispersion, deposition, and initial growth on the leaf surface. The issue appears complex, and they suggested more research is needed for a better understanding of these interactions.

In their experiments on sugar maple seedlings (60), Raynal and co-workers found seedling radicle elongation was reduced by pH 3.0 and pH 2.4 artificial throughfall treatments. These seedlings developed a soft black ring near the radicle tip. Upon microscopic examination the presence of bacteria was revealed in the damaged tissue.

Setliff and Manion (71) examined the effects of artificial acid rain on Scleroderris canker (Gremmeniella abientina) in red pine. The results of these studies were inconclusive but suggested that disease incidence may be more affected by acidic deposition impacts on competing microorganisms than by direct impacts on the pathogen species itself.

Research on the effects of precipitation acidity on plant pathogen-host interactions to date has provided us with a picture of the complexity of this topic, yet no general conclusions can be drawn for field conditions (72).

Cox (58) studied the effects of varied Cd and pH levels on pollen germination and pollen tube growth for forest species. Inhibition of these reproductive processes exhibited a synergistic response for the pH 3.6 and 50 μm Cd treatment combination. Lower concentrations of Cd, such as would be expected in ambient rainfall, actually stimulated pollen germination and pollen tube elongation. They felt Cd should be grouped with Pb and Mg as elements also found to stimulate these processes at levels found in ambient rainfall. Either stimulation or inhibition of these processes can alter the physiological timing sufficiently to reduce reproductive efficiency.

Abrahamsen (65) discussed the synergistic possibilities for SO_2 and O_3 synergistic effects on forest vegetation. As an example, he cited evidence of injury to white pine clones where 0.05 ppm O_3 or 0.025 ppm SO_2 caused injury to 0 and 20 percent of the clones, respectively. When these two treatments were applied simultaneously, 100 percent of the clones were injured.

It should be mentioned here that various acidic deposition related processes affecting the nutrient stress on trees are possible. Many of these are discussed more thoroughly in other sections of this bulletin. As an example, Rorison (73) has shown that an increase in N uptake can reduce plant tolerance to Al. Acidic deposition increases the availability of both of these elements to trees.

Greater levels of soil Al can cause an increased fixation of P in the soil, reducing this critical element's availability to tree roots. Additions of atmospheric N by acidic deposition could also improve forest growth to a level of inducing deficiencies in other essential nutrients (49). At the time of preparation of this bulletin, no studies were available to assess the direct, interactive effects of acid precipitation with gaseous air pollutants on tree growth.

D. Nutrient Uptake by Tree Roots

One of the mitigating factors which bridges the chemistry of soil and soil solution to the availability of nutrients for aerial tree components is the process of root uptake. Much of the availability of elements for plant uptake depends on soil chemical phenomena discussed in a later section. Acidic deposition-induced alterations to roots and rhizosphere composition can also affect uptake of elements by root systems.

McCormick and Steiner (74) evaluated eleven tree species to ten levels of Al in hydroponic culture. Levels of solution Al ranged from 0 to 280 ppm with hybrid poplar and autumn-olive being most sensitive to Al-induced reductions in root elongation. Alder, birch, pine and oak were much more tolerant, and exhibited no effect at concentrations as high as 80 to 120 ppm Al in solution.

Following up on the apparent tolerance of paper birch to Al, a subsequent study was conducted to determine if provenances (a provenance being the geographic area and environment to which the genetic constitution of parent trees for a species have adapted) within this species exhibited significant tolerance differences (75). In this study provenances, but not families within provenances, showed significant differences to Al tolerance with respect to root elongation. Exposure to 120 ppm Al caused decreased concentrations of Ca and Cu, decreased or nearly unchanged concentrations of P and Mg, and increased concentrations of Al, B, and Mn in foliage. Intolerant provenances generally had higher Al concentrations in foliage when compared to tolerant provenances. Beech would appear to be significantly more sensitive than these species, since Ulrich et al. (76) suggested toxicity for this species occurred at concentrations of 1 to 2 mg/l Al in soil solution.

Krause (77) recently discussed some of the implications of acid rain for forest ecosystems in New Brunswick. He pointed out that acid rain damage is less imminent in soils with a high organic matter content and in sites where an organic forest floor, rather than the mineral soil, supplies most of the tree nutrients. This is an essential consideration for many of the eastern Canadian and northeast United States commercial timberlands where softwood forests develop thick surface accumulations of organic matter. Fine tree roots inhabit this forest floor, which is highly buffered to chemical alterations, and are supplied with much of their nutrient requirements.

Ogner and Teigen (78) conducted a three-year pot experiment on two clones of Norway spruce using acid irrigation treatments at pH 5.4, 4.0, 3.0 and 2.5 in a solution matrix quality resembling average southern Norway precipitation. Their results showed that N was the limiting growth factor. Increased irrigation acidity caused a decrease in Ca, Fe, and Mn uptake by plants with a simultaneous increase in Al uptake. Clonal differences in growth caused an effect on soil acidity twenty-five times greater than that introduced by acid irrigation in an amount equal to the annual acid precipitation in southern Norway.

Cronan (79) recently discussed the results of a laboratory microcosm study designed to examine controls on leaching from forest floors. He pointed out that there may be significant differences between experimental laboratory systems and field conditions for those ions strongly influenced by plant uptake such as K^+, NH_4^+, NO_3^-, and SO_4^{2-}.

E. Stand Structure and Tree Growth

The focus of research discussed in this bulletin is the documentation of possible changes in tree growth which could result from the interaction of acidic deposition with forest ecosystems. While a direct desiccation of tree leaves by falling acids would be easily documented, no such clear cause and effect is presently occurring or seems likely to be demonstrated at ambient levels of acidity in the near future. Acidic deposition more likely describes a phenomenon which results in subtle alterations in the overall equilibrium of natural communities which are best identified over longer periods of time.

Loucks (80) recently discussed measures which could be used to quantify pollutant impacts on forest stands. He presented a useful classification of two general groups of measures: "indicators", defined as individual high-resolution response measures of components within the ecosystem (i.e. soil nutrient measures); and "integrators", defined as a measure reflecting the combined action of several environmental factors affecting an aggregated response in ecosystem components (i.e. forest site index). The author then described a potentially useful approach to quantifying acidic deposition impacts on forest productivity through the use of site index models as a key tool.

(1) Tree Growth Decline - The decline in the rate of growth for commercial timber species is of utmost concern to the forest products industry. As stated earlier, no direct impacts of acidic deposition on forest growth has been shown in the scientific literature. Recently, however, significant declines in the growth of several pine species, chestnut oak, and red spruce have been reported for the northeastern United States in areas which would be considered sensitive due to factors such as poorly buffered soils or high elevations. Investigations have

not been able to correlate growth declines with selected environmental parameters (e.g. climate, pathogens) which could be responsible for inducing the apparent stress on these ecosystems. To date, acidic deposition remains one of the possible factors contributing to decline in tree growth which demands further study in describing the causes for observed trends (10).

Johnson et al. (163) recently reported on research revealing abnormal decreases in the growth rates of pitch, shortleaf, and loblolly pine from plantations and native stands in the New Jersey Pine Barrens. Statistical analyses on 176 tree cores showed strong evidence for above normal decreases in growth rate over the past 25 years. Temperature, moisture, sunshine, and pH were important variables related to growth. Stream pH was found to be a good indicator of precipitation pH. Using multiple regression analyses, they found stream pH, in nearly all combinations of independent variables, was significantly and positively correlated with tree growth. These authors suggested that the concommitant shift in growth patterns and stream pH indicate acid deposition could be suppressing pine growth in these areas. White pine was also examined but did not show results similar to the other pine species, which was considered presently inexplicable.

Research on forest ecosystems of the western slopes in Vermont's Green Mountains have shown a decrease in red spruce growth. Siccama et al. (81) found declines in both basal area and density were evident between 1964 and 1979. These authors discussed indications of a similar situation which may be occurring in the Adirondack and White Mountains. For the basal area and density data collected it appeared that these measures have declined by 50 percent, with this trend apparently continuing as of 1981. They suggested the decline was not logically related to successional development or climatic change. Acidic deposition was considered a possible cause, yet the effects of insects and diseases have not been evaluated. The characteristics of red spruce mortality are a general browning and loss of needles from the crown apex downward and from the terminals of lateral branches inward over several to many years.

Puckett (164) investigated the applicability of using dendrochronological techniques in evaluating acidic deposition-induced alterations in white pine, eastern hemlock, pitch pine, and chestnut oak. Two cores from a minimum of 15 trees per species were sampled. The study was conducted on tree data from the Shawangunk Mountain area of New York for the time periods 1901 to 1920, 1926 to 1945, and 1954 to 1973. Through the use of regression analysis with orthogonally transformed temperature and precipitation data, the author found a significant shift in the response-function relationship for tree growth corresponding to the suspected increase in acidic deposition during the 1950's. Statistical tests indicated the shift was nonclimatic.

Care must be taken in using measurements of radial tree growth, or tree-ring analysis, in describing air pollutant effects on forest growth. Due to the sensitivity of diameter growth to other factors such as age of individual trees, the effects of competition from nearby stems, annual variations in climate, pathological effects, and local soil influences, these techniques must be carefully evaluated for use as a tool in revealing acidic deposition influences on forests (80).

Alterations in natural forest ecosystems resulting from the deposition of acidic materials and acid precursors is more readily discernable near point sources of emissions. Rather than the oxidized form of S common to acid precipitation, damage near industrial facilities is usually attributable to gaseous SO_2 impacts. Freedman and Hutchinson (82) quantitatively analyzed forest communities along a south-southeast transect from the 70 to 80 year-old Sudbury, Ontario smelter complex in Canada. They found no forests existed within 3 km, pockets of forests existed within 8 km, and bare hilltops were evident within 15 km of this smelter. Forests nearest the smelter were described as "depauperate" in terms of tree diversity and biomass, with forest canopies exhibiting greater impact than ground flora. Conifers, bracken fern, lichen, and bryophytes were considered most sensitive to this pollution.

(2) The German Hypothesis - The evidence suggesting damage in forested areas has been found in Germany, Czechoslovakia, Sweden, New York, Vermont, and New Hampshire, according to recent reports by Tomlinson (83,165). The most intensive research relating to this phenomenon has been carried out in Germany on beech and spruce forests where acidic deposition is considered a major cause of the observed tree growth declines.

From his investigations in the Solling forests of West Germany, Ulrich (84,85) decribed the effects of acidic deposition and air pollution as a multiple phase process. The first phase is a net accumulation of air pollutants as nutrients (Ca, Mg, NH_4, NO_3), acids (H_2SO_4, HNO_3, HCl), and toxins (SO_2, HF, heavy metals, organic compounds) in the ecosystem. This phase may often be associated with increased tree growth due to nutrient inputs, particularly N, where 20 to 50 percent of the stand requirements can be supplied by atmospheric sources.

The second critical phase is destabilization. This phase is marked by Al toxicity-induced decreases in decomposer activity, tree root damages, a marked increase in internal acids in the ecosystem, and an accumulation of toxic heavy metals in leaves, bark, and the forest floor (primarily Zn, Cu, and Pb).

Dr. Ulrich suggests that a rapid increase in soil acidification and destabilization occurs after the decomposer organisms are damaged, which may explain the sudden increases in forest damage observed in Central Europe over the last few years.

Another possible factor in these forest declines suggested by Dr. Ulrich is heavy metal accumulations. Visual symptoms associated with heavy metal toxicity are (a) bark necrosis on upper crowns and single trees exposed to high deposition rates, and (b) continuous loss of green leaves and short twigs throughout the vegetative period on beech, oak, and spruce.

The final phase of the overall process follows destabilization, and Ulrich calls this succession, whereby a new ecosystem replaces the existing forest community. He believes the ecosystem may recover if trees are replaced by grasses due to the lower dry deposition rates in grassland systems. He also has concluded that dense, pure, coniferous stands 20 to 40 years of age growing on acid soils are especially in danger of damage by acidic deposition. He stated that "....no forest ecosystem, even forests on calcareous soils, can withstand the present air pollution (in Germany) without serious damage." He believes in the long run, under Central European conditions, trees will not grow older than 50 years.

A recent report by Tomlinson and Silversides (165) on visitations to Central Europe indicated the die-back phenomenon is now being observed in both less severely impacted and less sensitive areas than originally was noted. This expansion of die-back regions with time is considered by the Germans to be indicative of the accumulative nature of the acidic deposition impacts on forests. The effect is thought to be primarily an indirect consequence of cumulative sulfur alterations to the soil, ultimately manifest as a decline in tree growth.

Recently the West German government released a report, "Forest Damage Due to Air Pollution," which was prepared by scientists and government officials as part of the German effort to evaluate the forest damage issue (179). The report draws upon available scientific information and a survey of forest damage in West Germany which was conducted during the summer of 1982. The survey was based on regional records and observations from forestry offices throughout the country, since no areawide, systematic evaluation of the forest damage problem has yet been carried out. Approximately 60% of the forested land area of West Germany was included in the survey. Of this, an estimated 560,000 ha was reported to show signs of damage which amounts to 7.7% of the total forested land area in West Germany. Within the forest damage area 75% was considered slightly damaged, 19% damaged, and 6% severely damaged. The proportion of land area showing damage for each species was 60% for fir, 9% for spruce, and 5% or less for other species including Scotch pine, beech and oak. It should be pointed out that fir covers a relatively minor portion of this country (0.16 million ha) while spruce is the dominant species (2.93 million ha).

In assessing causes of forest damage, the working group which developed this report examined the possible role of (a) SO_2, (b) NO_x, (c) heavy metals, (d) photo-oxidants, (e) hydrogen fluoride, (f) climatic influences, (g) forest cultivation effects, and (h) biotic factors in tree damage. They concluded that several factors generally contribute to forest damage and that it is the combination of factors, which varies between locations, which is critical in explaining the observed effects. They also pointed out that "while there is no natural scientific proof of this," the indications are that air pollution, probably SO_2 and its transformation products in particular, are significant causes of forest damage.

(3) Other Stand Structure Effects - Beyond the obvious effects that selective die-back of one tree species over another would have on stand structure, other aspects brought out by recent research should be noted. The studies of throughfall and stemflow in subalpine balsam fir by Olsen *et al*. (36), discussed earlier, pointed out the importance of stand density in acid precipitation distribution and alteration. Their research showed stemflow to be more acidic and chemically enriched than throughflow. With greater stand density, a greater partitioning of precipitation inputs to the stemflow component results in markedly altering the topographic distribution of acid inputs to the forest floor.

The forest stand is the essential unit of silviculture due to its uniformity in tree characteristics. The trees, however, are only one component in a natural community of interdependent organisms, and alterations to other community members by acidic deposition could affect future stand performance. Evans *et al*. (4) cited results indicating that ambient precipitation in the northeastern United States inhibits the reproduction of ferns. Horntveldt (86) found evidence of reduced moss cover in forests irrigated with acidified water.

VII RECENT RESEARCH: EFFECTS OF ACIDIC DEPOSITION ON FOREST SOILS

One of the most rapidly expanding areas of investigation with respect to acidic deposition effects on forest ecosystems is the consequences of this pollutant stress for forest soils. With readily observable direct impacts from this form of air pollution not presently shown or soon anticipated, the focus of concern has shifted to the subtle, long-term impacts of acidic deposition on the soil resource which could be reflected as changes in forest productivity. Many scientists have become concerned with the possibility of decreasing growth rates and mortality due to soil-mediated acidic deposition impacts, in important commercial timberland communities. Although the issue of forest soil effects is complex, the overall concerns center around (a) decreasing essential nutrient availability, and (b) increased activity of metals to levels toxic for tree growth.

Nutrient losses can result when the anions from acidic deposition (SO_4^{2-} and NO_3^-) accelerate leaching losses of critical cationic nutrients (e.g. Ca^{2+}, Mg^{2+}, K^+) due to the chemical requirement for maintenance of electroneutrality in solutions percolating through soils. Alterations in the microbiological soil community are suspected as a possible cause of decreased nutrient availability resulting from changes in the process of organic matter decomposition and carbon cycling. Due to increased atmospheric inputs and soil solution chemical alterations brought about by acidic deposition, some trace metals may reach soil levels which result in direct or indirect negative impacts on trees. These substances include Cd, Pb, Zn, Cu, Ni, V, Co, Mn, with the greatest concern being for the mobilization of Al in the soil.

Much of the recent work of forest soils with regard to the acidic deposition issue has taken an ecological approach to understanding the implications of soil phenomena on the entire forested ecosystem. This has ultimately provided a better understanding of the natural forest community; however, no sharp division exists between studies to allow a distinct classification of findings. The following groupings have been designed to facilitate this discussion with no further implications intended in the categorization process.

A. Potential Benefits to Forest Soils

In the earlier discussion of direct additions of nutrients to forest species from acidic deposition, it was pointed out that current knowledge does not allow a clear identification of the source for a particular element found in plant tissue. There exists the probability that the chemical elements which are supplied to forests through atmospheric deposition provide a valuable source of nutrients for terrestrial ecosystems. Indeed, the work of Tabatabai et al. (64), previously mentioned, showed this to be particularly true in the case of N, S, and P in unmanaged grassland ecosystems. Although some of these materials may be directly absorbed by aerial vegetative organs, a great deal of the plant assimilation of atmospherically contributed nutrients would be through root uptake from the soil-soil solution matrix.

Abrahamsen (65) listed the essential elements for plant growth as (a) the structural elements C, H, and O, (b) the major nutrients N, P, S, K, Ca, and Mg, and the minor, but still essential elements Fe, Mn, Cu, Zn, B, Mo, and Cl, though others may be included for specific plant species. He also discussed the importance of understanding how the law of limiting factors affects plant growth. Although it is realized today that the interaction of growth factors is a key concept in understanding plant growth, the basic law is still accepted and points out that growth is limited by the factor(s) in minimum supply.

In forest ecosystems throughout the world, the N supply has been identified as a key limiting nutrient for tree growth (49). This has been substantiated by much of the acidic deposition research where it has been found that the majority of atmospheric inputs of N are retained in the ecosystem and incorporated into the biomass (34,49,65,87). It is highly probable that, for N, the net benefits currently outweigh any negative impacts which may occur with respect to forest productivity.

Two points should be considered in regard to nutrient inputs for forest soils. First, since N is often the limiting nutrient for tree growth, N inputs have a potential to increase forest productivity. The growth rate would subsequently improve until limited by N supply or some other growth factor(s). If the N supply is adequate but some other nutrient subject to acidic deposition-induced leaching losses (e.g. Ca, Mg) becomes limiting, then the very process which improved growth would also have antagonized the severity of this secondary growth limitation. Overall, in the short-term, the result is improved productivity, yet understanding the total impact is obviously more complex than it initially appears. There also exists the possibility of a net loss in productivity in the long-term due to chronic depletion of critical nutrients or changes in organic carbon cycling. Secondly, any evaluation of the impacts of acidic deposition on forests must take into account the value of the added nutrients as an economic asset in terms of fertilizer costs.

Other essential plant nutrient inputs to forested ecosystems from what Puckett (164) refered to as the "acid rain-air pollution complex" also could benefit forest growth should these substances be currently limiting growth factors. Johnson et al. (49) discussed areas where S is a limiting tree growth factor such as in eastern Australia and the northwestern United States. Deposition of S in these regions could have positive growth effects. Ulrich (85) stated the supply of N, K, Mg, Ca and S required for the biomass production in Solling timber stands of Germany since 1950 originated entirely or predominantly from air contaminant deposits.

Lindberg et al. (88) studied the deposition of metals to the forest canopy at Walker Branch Watershed in the Tennessee Valley and reported significant inputs of Cd, Mn, Pb and Zn. Neglecting the toxic potential for the purpose of this discussion, these element additions would undoubtedly inhibit critical shortages in the availability of the essential micronutrients Mn or Zn for future forest growth.

Although much of the research on soil biological effects of acidic deposition have focused on negative impacts, some species may benefit from the possible chemical alterations in the microenvironment. Hagvar and Abrahamsen (89) found that while some species of microarthropods could not tolerate acid conditions, others showed a marked preference for the more acidic environment. Whole groups of microorganisms may be favored by acid soil environments as witnessed by the greater ability of fungi, relative to bacteria, to survive low soil pH conditions (90).

B. Leaching and Ion Exchange Processes

A major concern with respect to the long-term impacts of acidic deposition on forest productivity has centered on the possible nutrient depletion which could result from H_2SO_4 and HNO_3-dominated soil solutions. In areas impacted by acidic deposition, the H^+ cation in precipitation, throughfall, and stemflow can replace essential cationic plant nutrients (e.g. Ca^{2+}, Mg^{2+}, K^+) upon interaction with soil colloids. The displaced cations can then be easily leached from the soil when associated with the charge balancing SO_4^{2-} and NO_3 anions, provided these anions are not retained in the solum through soil sorption or root uptake processes. Abrahamsen and Tveite (91) recently emphasized that the rate of weathering in nutrient-poor soils does not appear to compensate for the increased leaching losses.

Although the bicarbonate anion (HCO_3^-) is an important component in mildly acid to neutral, "natural" forest soil solutions, areas receiving S and N inputs via acidic deposition have soil solutions dominated by the strong mineral acids H_2SO_4 and HNO_3. The nature and behavior of organic acids appears also to play an important role in forest ecosystems with respect to acidic deposition impacts and acid neutralization.

Ulrich (84) recently discussed some of the problems which appear to be occuring in the forests of central Europe. As a result of leaching losses from soil acidification, Mg deficiency symptoms have appeared in conifers as yellow colored needles which are most evident in spring. He stated that boron (B) is also leached, and that while no evidence exists for deficiency symptoms, decreased wood tensile strength due to a lack of this element cannot be discounted. He also believes that the leaching of base cations from the rooting zone is complete in many Central European forest soils with Ca^{2+} saturation of the cation exchange capacity often less than 5 percent.

Mollitar and Raynal (92) studied the potential effects of acid precipitation on a hardwood and coniferous stand in the Huntington Forest near Newcomb, New York. Solution chemistry was studied as bulk precipitation, throughfall, and soil solutions at the base of the O_2, A_2, and B_{23} horizons. The concentrations of NO_3^-, H^+, and K^+ in soil B horizon leachates were not significantly different from precipitation concentrations, while SO_4^{2-}, Ca^{2+}, Mg^{2+}, and Na^+ concentrations were significantly greater. Mean bulk precipitation pH was 4.2 (63 µg H^+/l) for the study. Conifer site throughfall, forest floor leachates, and A horizon leachates were significantly more acid than corresponding hardwood strata, yet solutions at the base of the B horizon in both stands did not differ significantly. It appeared that H^+ ion acidity was effectively neutralized in the soil while NO_3^- and K^+ ions were conserved. Sulfate and organic anion leaching were of equal importance in the hardwood site whereas organic anion leaching dominated the conifer site. The authors concluded that low concentrations of exchangeable cations in these soils suggest chronic leaching losses of nutrient cations may adversely affect forest productivity.

Cronan (79) subjected forest floor samples from a subalpine coniferous forest in the White Mountains of New Hampshire to three simulated throughfall (pH 3.5, 4.0, and 5.7) and two temperature treatments (6° and 24°C) in a laboratory microcosm study. Results indicated that as treatment acidity increased, mass action ion exchange between H^+ ions and exchangeable cations in the forest floor caused increased leaching losses of Ca^{2+}, Mg^{2+}, K^+, and NH_4^+. Higher temperatures also increased leaching losses of Ca^{2+}, K^+, NH_4^+, SO_4^{2-}, NO_3^-, and organic anions due to increased microbiological decomposition of the organic substrate. The author pointed out the significant effects mineral soil retention and plant uptake may have on leaching losses under field conditions.

Johnson (93) proposed an interesting conclusion with respect to the sensitivity of soils to groundwater acidificaton due to acid and sulphate inputs. Due primarily tc the well known "salt effect" phenomenon described by soil chemists, it appears that those soil solutions that are already acid are most susceptible to further acidification, whereas the least acid solutions would be most resistant. Johnson explained that since the exchange complex is dominated by H^+ and Al in acid soils, inputs of a mobile anion (i.e. SO_4^{2-}) from acid precipitation would require an equivalent increase in solution cation activity, thus elevating H^+ in soil solution or decreasing pH. In less acid solutions, H^+ constitutes a lower proportion of the total cations and thus would contribute less to increased soil solution ionic strength at equilibrium. In no case did the author feel that projected changes in acidity for the Alaskan ecotypes studied were cause for alarm.

One aspect of many forest soils which has been shown to be critical in understanding ion exchange relationships in these ecosystems is the tremendous contribution by organic materials to the cation exchange capacity (34,94). Highly organic forest floors, or humus materials, and mineral soil organic content are directly associated with soil cation exchange capacity. Cation exchange capacity originating from organic materials is considered pH-dependent, which means a decrease in soil pH would also reduce the cation exchange capacity resulting in a lower soil capacity to retain cationic nutrients. Kalisz and Stone (94) demonstrated this phenomenon when they measured the cation exchange capacities of acid forest soil mor and mull samples from New York at field pH (pH 4 for mors and pH 4.9 to 5.4 for mulls) and at pH 7.0. Cation exchange capacities increased from 52 and 123 meq/100 g organic matter at field pH to 183 and 236 mg/100 g organic matter at pH 7 for the mor and mull samples, respectively.

Norton _et al_. (95) discussed the implications of their research with regard to the effect acid precipitation is having on forested ecosystems in eastern North America and the Pacific Coast states. They concluded the increased acidity in precipitation, and associated heavy metal deposition has caused the accumulation of heavy metals (e.g. Pb), and the leaching of cations (e.g. Al^{3+}, Ca^{2+}, K^+, Mg^{2+}, and Mn^{2+}) in forest soils for these regions. Their conclusions were that decreases in forest productivity will occur in the northeastern United States due to diminishing nutrient pools for these ecosystems.

A recent conference in Sweden on acidic deposition brought together experts from throughout the world on the ecological impacts of this environmental problem (8). In their conclusions, they stated that the exchange of H^+ in acid percolating waters will increase Ca^{2+}, Mg^{2+}, and K^+ leaching losses, and in soils below pH 5.0, increase the mobility of the potentially toxic Al, Mn, Cu, Cd, and Zn metals. These exchange processes with basic cations neutralize the water but acidify the soil. They felt soil acidification due to acidic deposition should be detectable over a 10 to 50 year period. Ulrich (85) indicated a pH decrease over the last 20 years in Germany has been observed for the areas of Solling, Munster, and Berlin.

Theoretical calculations to examine the potential impact of acid precipitation on leaching and soil acidification may lead to significantly different results, depending upon the assumptions on which conclusions are based. In an earlier study of acidic deposition effects on soils, McFee et al. (166) calculated that 100 years of pH 4.0 acid precipitation would cause a 0.8 pH unit decline and 20 percent decrease in base saturation for a typical midwestern forest soil. Strayer and Alexander (167) recently used the same assumptions but made these calculations for the top 1.0 cm of soil depth and found only 5.2 years of pH 4.0 precipitation would be needed to produce the same results.

C. Organic Matter Decomposition

The soils' organic matter content and composition has long been recognized as a key factor in evaluating soil chemical and physical behavior. Agronomists have used this knowledge to manage agricultural soils for improved fertility and structure which is reflected in greater yields of marketable products. For forested ecosystems, the various aspects of soil organic matter content, composition, and distribution is just beginning to be understood. It appears that the importance of this material, and the rate of carbon cycling, may be more significant in forests than most prior experiences have shown for agronomic crops. Much of the nutrient pool available for trees in many temperate climate forests is thought to be associated with the forest floor and mineral soil organic matter content. A major concern with respect to acidic deposition impacts is that the rate of organic matter decomposition could be reduced, which would have the effect of tying up essential nutrients in the larger reserve of undecomposed organic materials. Some evidence exists indicating this may already be occurring in the northeastern United States (37).

Hovland et al. (96) examined the effects of dilute H_2SO_4 treatments (pH 2 and 3) and distilled water on the decomposition of spruce needles in a laboratory lysimeter experiment which was sampled after 16 and 32 weeks. The order of mobility for elements leached from tissues was K>Mg>Mn>Ca, with K loss showing the greatest sensitivity to leachate volume and Ca loss being most sensitive to leachate acidity. The evolution of CO_2 and changes in tissue dry matter, lignin, mannose, and xylose indicated treatment acidity promoted decomposition at first, but was followed by a period of reduced decomposition for the less easily degradable substances. Even the most acid treatments in this study reduced dry matter losses by less than 5 percent.

Locanzo and Morrison (97) looked at hardwood sites near the Sudbury, Ontario metal ore smelter which were subjected to various levels of wet and dry deposition. Research on forests in this area was also discussed earlier in connection with the work done by Freedman and Hutchinson (82). Locanzo and Morrison found total organic matter content, N concentrations, and cation exchange capacity of the surface organic horizons between sites impacted by varying levels of deposition did not differ significantly. In contrast to the surface organic horizon, total organic matter, N, and cation exchange capacity in the underlying mineral soils decreased significantly with increased levels of deposition damage to forests. The authors attributed these differences in mineral soil properties primarily to alterations in composition of the vegetative cover on the site.

Francis (98) studied the effects of soil acidity on the microbial decomposition of organic matter and N transformations in an acid forest soil. Using amendments of oak leaves and pH adjustments, the author reported naturally acid and acidified forest soils had slow rates of nitrification and denitrification, and low bacterial populations. Overall, he concluded that acidification of forest soils by acid precipitation may lead to significant reductions in leaf litter decomposition and N recycling.

Much of the theoretical interpretation of acidic deposition impacts in German forests deals with what Ulrich has described as a spatial and temporal "discoupling" of the ion cycle (76, 99). This is associated with a shift in the soil state that results in greater storage of N-poor organic matter in the forest floor with elevated Al concentrations in soil solution. These changes in decomposition conditions due to acidic deposition bring about the accumulation of C, N, P and Ca within the humus layer (100).

Studies on forest soil organic horizons indicated that the microarthropod group of soil fauna may also be sensitive to acidic deposition-induced alterations. Hågvar and Abrahamsen's study (89) indicated species varied in their reaction to both acidification and liming. Overall, acidification decreased the rate of humus decomposition in these experiments.

D. Impacts on Soil Microbiology

Investigations to evaluate deposition impacts on the microbiological community in forest soils usually also deal with the closely aligned relationships with soil organic matter. David et al. (168) recently discussed their research on Adirondack forest soils, illustrating the close association between total organic matter and microbial biomass, with accumulations of both evident in the O1, O2 and B21h horizons.

Much of the impetus for studies on soil microflora have resulted from a desire to better understand possible alterations in soil organic C and nutrient cycles resulting form acidic deposition. One effect which has been reported is the reduction in soil bacterial populations due to soil acidification (101). Hileman (3) cites Bruck who reported that the microbial diversity of poorly buffered Adirondack soils has decreased, becoming dominated by bacteria, Pythium, and Phytophthora.

The results from this area of investigation dealing with microbiological processes have produced varied results. Hovland (102) measured the effects of artificial acid rain on respiration and cellulase activity in spruce needle litter. He found no effect on the respiration of this material to be attributable to increased acidity. Gibson and Lindhurst (26) pointed out that it is difficult to distinguish between direct effects of acidification from those induced by altered soil solution chemistry or toxic metal leaching in soil biology studies. They also cited studies indicating differential tolerance of algae species to soil acidity, decreased N fixation by lichen under low pH precipitation, and the dominance of fungi in acid soils compared to other groups of microbiological organisms.

The study by Francis (98) indicated that organisms involved with N transformations were sensitive to soil acidity. Increased acidity was associated with decreased rates of ammonification, nitrification, and denitrification, with the latter having N_2O as an end product at greater acidities. The abundance of N-fixing free-living bacteria was low in acidic and acidified forest soils which the author felt may indicate that asymbiotic N fixation contributes insignificantly to forest N inputs.

Strayer and Alexander (167) exposed samples of forest soils to simulated acid rain for a period of seven weeks to measure the effects on glucose mineralization rates and chemical properties. Treatments for soils were based on ambient precipitation chemistry which averaged pH 4.0 to 4.1 with further acidification of this solution carried out for some applications. Acid rain treatments lowered pH values, increased total and exchange acidity, increased exchangeable Al, and decreased the heterotrophic microorganism activity. The authors stressed that acidic deposition impacts on forest soils occur in a sequential manner from the surface downward. Significant effects of acidic deposition which are manifest in the surface soil layers may have an impact on soil microbiology due to the concentration of microbiological activity near the soil surface. However, examination of an entire soil column may have suggested no influence in the same sample demonstrating a surface effect.

Wang et al. (90) conducted a series of experiments to evaluate acidic deposition effects on microbial populations in Adirondack forest soils from the Huntington Forest in Newcomb, New York. They examined the microbial community in soil and litter under a beech and maple stand, and red pine plantations. In the hardwood stand the populations of bacteria, actinomycetes, and fungi closely paralleled changes in soil acidity. Microbial populations in softwood sites were not correlated with characteristics of the site. In a soil microcosm study these workers also found acid treatments increased fungi and actinomycete populations which they suggested may be caused by reduced competition from bacterial populations.

Alexander (103) also considered decreased competition from other heterotrophs as a possible explanation for the relative abundance of fungi with decreased pH. He listed the six major microbial groups in the underground ecosystem as being (a) bacteria, (b) actinomycetes, (c) fungi, (d) algae, (e) protozoa, and (f) viruses.

Hågvar and Abrahamsen's work (89) on microarthropod reaction to varied soil pH indicated distinct differences in pH preference between genera. This study evaluated the populations of Acari, Collembola, Protura, and Enchytraeidae in raw humus and mulls of varied quality from Norway spruce stands. It appeared that soil pH was correlated with reproduction success in several species. For example, Aurida pygmaea was common to acid Norwegian coniferous forests, Isotoma notabilis clearly preferred high soil pH, while Isotomiella minor seemed indifferent to the pH factor.

E. Mineral Weathering

Considerable research has been done over the years to describe the causes and mechanisms which control pedogenetic processes under ambient conditions. Thermodynamic calculations have traditionally assumed precipitation pH to be roughly 5.6, and to be controlled by an equilibrium with atmospheric CO_2. The chemical properties of atmospheric deposition strongly influence the equilibrium conditions which control the direction and rate of mineral weathering for the landscape. In most northeast forest soils, the soil solution is dominated by SO_4^{2-} rather than a carbonate species (37). This indicates that a very different equilibrium with minerals present will be established by soil solutions than what would be expected from theoretical calculations using "non-polluted" conditions.

Another aspect of acidic deposition impacts on mineral weathering deals with the rate of weathering for soil minerals or underlying bedrock. Weathering of most minerals (quartz is an exception) leads to the consumption of H^+ ions and the release of bases (104,105). The greater the acidity, the greater the rate of mineral dissolution in soils and bedrock.

Bache (105) recently discussed the critical factors controlling the rate of mineral decomposition, and thus the rate of acid neutralization by this mechanism. The two general factors are (a) rock composition (or content of weatherable minerals) and (b) access of percolating waters to rock surfaces. The key to the ability of rock weathering mechanisms to neutralize acid inputs depends on (a) the pattern of water flow, and (b) the residence time for solutions. He concluded that the capacity for rocks and minerals to neutralize acidity is infinite, but without adequate contact between minerals and solutions, these solutions may retain electrolytes and acquire further acidic components from the surface layers of the soil.

Johnson _et_ _al_. (106) published an excellent study of the interaction between acid rain, aluminum solubility, and chemical weathering in the Falls Brook watershed at the Hubbark Brook Experimental Forest in New Hampshire. Although the chemical weathering of primary aluminosilicates provides the ultimate sink for H^+ and Al acidity, these authors described a two-step mechanism of acid neutralization which probably is active at Falls Brook and most acidic deposition-sensitive regions.

In the first step, incoming precipitation acidity, which is almost totally H^+ ion acidity, is initially neutralized by a "relatively soluble aluminum mineral, probably $Al(OH)_3$." The soil solution is enriched in Al acidity (and depleted in H^+ ion acidity) by the time it first appears as streamwater. The source of Al for water percolating through the soil appeared to be primarily from the humus and B2 soil horizons. The second step entails the neutralization of H^+ and Al acidity by the weathering of primary aluminosilicate minerals which releases bases (primarily Ca and Na) into solution. The critical factors which they pointed out as controlling the neutralization process were (a) water residence time in the soil zone, which is directly related to stream order, and (b) the rate of weathering of the primary aluminosilicate soil minerals. They also found that the proportion of the organically complexed Al increased steadily in the downstream direction.

Pačes (107,108) has examined the effect of man's activities on mineral weathering and runoff composition in central Europe. He found agricultural practices intensify the oxidation of pyrite and runoff acidity. Dissolved Al was considered the best indicator for the effects of acid rain on rock weathering. By comparing the results of river water analyses in 1892 and 1976, he determined 88 percent of the NO_3^-, 82 percent of SO_4^{2-}, 77 percent of Cl^- and 72 percent of Na^+ were currently of anthropogenic origin and not the result of natural weathering. His calculations also showed that environmental acidification in the Elbe River Basin has increased the rate of mineral weathering from 10 cm to 30 cm per 1000 years in catchments underlain by gneisses and granites. It seemed that SO_4^{2-} and NO_3^- may originate from various sources but high Al always seems to indicate severe environmental acidification.

F. Heavy Metals and Micronutrients

Meaningful efforts by the scientific community to understand the effects of acidic deposition components on forests must include an evaluation of the intimately associated forest interactions with heavy metals. The processes which produce atmospheric acids and acid precursors also contribute a variety of trace metals to the environment. Concern over the possible toxic consequences of elevated trace metal levels in the soil environment arise from (a) the deposition of these materials from the atmosphere, and (b) the increased mobility of trace elements in the soil environment resulting from greater levels of acidity. It is a well known phenomenon to environmental chemists that most trace elements, a notable exception being the micronutrient molybdenum, become more soluble or active in soil solutions with decreasing pH. A closely related concern is for the acidic deposition-induced mobilization of potentially toxic metals which are then transported in groundwaters to lakes and streams with harmful consequences for aquatic systems. Some evidence appears to already exist, suggesting accelerated leaching of Mn and Zn due to acidic deposition has occurred in areas from Vermont to the Gaspe Peninsula in Canada, while Pb, Cu and Zn are accumulating in this region's soils (37).

Lindberg *et al.* (20,88) have investigated the wet and dry deposition of various trace metals at the Walker Branch Watershed in eastern Tennessee. They found in one study that almost 100 percent of the Pb, 30 to 40 percent of the Cd and Zn, and 10 percent of the Mn flux to the forest floor during the growing season resulted from atmospheric deposition. The contributions of wet versus dry deposition were comparable for Pb, whereas wet precipitation dominated Cd and Zn inputs, with dry deposition playing the key role for Mn.

McColl (109) measured Cu, Fe, Zn, and Mn concentrations in bulk precipitation, throughfall, stemflow, and in soil solutions at 10, 15, 25, and 30 cm depths for a *Eucalyptus globulus* forest in the Berkeley Hills of California. As a group, the elements Cu, Fe, and Zn behaved similarly, but Mn did not follow the same trends. Dry deposition by impaction on the forest canopy dominated Mn and Zn inputs. Rain was the primary source of Cu and Fe inputs. All metals measured were negatively correlated with pH in the soil solution. Uptake of Mn by plants and its concentration in the various components measured far exceeded concentrations of the other elements in this study.

Percy (110) described the heavy metal and S inputs to Sphagnum magellanicum Brid. within the Maritime Provinces of Canada. Measurable inputs of all elements measured were found which included Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, S, and Zn. Elements accumulated in the order S>Fe>Mn>Zn>Pb>Cu>Ni>Cr>Co >Hg>Cd with significant correlations for concentrations between the element pairs Fe-Co and Ni-Cr.

Locanzo and Morrison (97) examined wet and dry deposition to hardwood sites downwind of the Sudbury smelter complex in Ontario, Canada. The more highly impacted sites (3 km downwind of the Coniston smelter) showed decreased Ca, Mg, Mn, and Zn in tissue which was a reflection of decreased soil levels. On the other hand Cu, Al, Co, and especially Ni were at critically high concentrations in soil. The authors pointed out that such complex interactions as Ni-induced Zn deficiency must also be addressed in the interpretation of these types of data.

As part of their work on tree establishment for the polluted soils near Sudbury, Locanzo and Morrison (111) treated white pine and white spruce seedlings with Ni and Cu solutions in growth chambers. After a 20-week period, substantial growth reductions occurred when Ni and/or Cu concentrations equalled or exceeded 10 ppm in nutrient solutions. Foliage Ni and Cu concentrations increased in relation to their concentration in solution. Foliar concentrations of Fe decreased in relation to Ni and Cu supply; Zn decreased in relation to Ni supply only.

Tyler (112) quantified the amount of Na, K, Mg, Ca, Al, Fe, Mn, Ni, Cr, V, Cu, Zn, Cd, and Pb leached from the Podzolic A-horizon of a spruce forest soil in southern Sweden over a 2.5 year period. He found conditions which favored the leaching of organic matter, Fe and Al (i.e. relatively high temperature and precipitation periods) were associated with considerable losses of Pb, Cr, Ni, and V from the A horizon. Metals which occurred largely in the exchangeable fraction (e.g. Mg, Ca, Zn, Cd) were more susceptible to minor fluctuations in pH. He stated that accelerated internal production or atmospheric deposition of acidic materials would reduce the retention time for this second group of elements.

Tyler (113) later discussed the influences of the metal polluting industry on forest soils in Sweden. He pointed out that acidic deposition combined with metal deposition seemed to increase the toxicity of metals in forest soils influenced by the higher metal inputs. However, he concluded that it is not yet possible to determine whether acidic deposition causes adverse effects on decomposition, mineralization, or toxic metal availability at background concentrations in soils. Due to its accumulation in the food chain and mobility in soils, Cd appears to pose the greatest heavy metal toxicity problem in Sweden today (169).

G. Nitrogen Chemistry

The chemistry of N plays an important part in the interactions between acidic deposition and forests. Nitrogen is a major cause, along with S, of the acidity in precipitation due to the formation of HNO_3 in the atmosphere. Upon interaction with the terrestrial ecosystem, N is readily taken up by vegetation and incorporated into organic compounds. This is especially true in forested ecosystems where N is usually a limiting nutrient and therefore readily taken up by the tree roots. Johnson *et al*. (114) recently compared N and S cycles in forests and stated both elements are accumulating in forests at the Walker Branch Watershed, and are involved in protein synthesis. These two elements differed, however, in that N supplies were limiting, whereas S was in excess of vegetation demands. They summarized the behavior of these elements as (a) N cycling being dominated by biological processes whereas (b) S cycling is dominated by geochemical processes.

Total N content is usually reflected by total organic matter content in forest soils. Decreased rates of organic matter decomposition due to acidic deposition would imply an immobilizaton of critical nutrients, particularly N, in the undecomposed organic material. On the other hand, environmental conditions favoring the decomposition and mineralization of soil organic materials would increase the production of HNO_3 and organic acids in soils. Ulrich (85) referred to this relationship when he recently described acidic deposition-induced ion decoupling processes for German forest soils. In discussing the internal H^+ ion transformation in soils, he stated, "Due to the quantitative importance of nitrogen in this transformation, we can state in simplified form that, as a general rule, nitric acid occurs with mineralization, while nitric acid is absorbed with ion absorption."

Nilssen *et al*. (170) pointed out that N is generally the nutrient taken up in greatest amounts by plants. Since N may enter the roots as NH_4^+ or NO_3^-, this element plays a critical role in determining the cation/anion balance of soil and plant solutions. They stated that in temperate and boreal forests, N is primarily taken up as NH_4^+, with little nitrification occurring. Uptake of N by tree roots as NH_4^+ should be mainly associated with a net release of H^+. Complete mineralization of organic matter would counteract this acidity. Temporal differences in these two processes, however, could lead to periods of increased acidity prior to complete mineralization.

Galloway and Dillon (115) discussed the role of N in the acidic deposition issue. They pointed out that the major forms of N in wet deposition are NH_4^+ and NO_3^-, with dry NO_x deposition considered to be rapidly oxidized to HNO_3 in the soil environment. They summarized the fate of NH_4^+ in terrestrial ecosystems as (a) oxidation to NO_3^-, with the subsequent production of two equivalents of acidity, (b) uptake by roots producing one equivalent of acidity for each equivalent of NH_4^+ taken up, or (c) discharge from soil solutions into lakes. They showed data indicating most NH_4^+ deposited is retained in the watershed, therefore having an acidifying effect by the first two processes listed.

These authors summarized NO_3^- retention mechanisms in the watershed as (a) assimilatory reduction or uptake producing a maximum of one equivalent of alkalinity for each equivalent of NO_3^- taken up, (b) dissimilatory reduction as denitrification or ammonification which produces a maximum of two equivalents of alkalinity for each equivalent of NO_3 reduced, and (c) discharge from soil solutions to lakes or streams. They pointed out that the amount of acid consumed in the first two processes is greater than the NO_3 retained; therefore the alkalinity produced only partly counters the associated strong acids. To fully understand these processes, the cations and anions associated with NH_4^+ and NO_3^- in deposition and soil solutions must be known.

Several efforts have been made to apply modeling techniques to N cycles in terrestrial ecosystems. Aber et al. (116,171, 172) reported on work utilizing the JABOWA and FORTNIT simulation models to describe the effects of acid precipitation on soil nitrogen and forest productivity. They pointed out that, to date, acid precipitation has not been shown to change forest production. Five factors suggested as delaying or counteracting a growth response are (a) acid precipitation may not significantly acidify soils compared to natural processes, (b) pH may not affect N mineralization, (c) decreased N mineralization may offset N inputs, (d) short-term N depletion may be compensated for by translocation of N in tissue, and (e) the vegetation may be tolerant of N depletion. Their results from computer simulation models suggested that since N is a limiting nutrient, acid precipitation impacts on pH-sensitive N availability processes may potentially alter forest growth.

Ågren (117) used modeling techniques to evaluate C and N cycles in Scots pine and Norway spruce. Of prime concern in this research was the evaluation of acidic deposition N additions to soils versus decreased N mineralization rates. His results showed site quality to be critical to impact evaluation. For example, poorer forest sites were considered most susceptible to decreased mineralization but had the greatest capacity to absorb incoming N before reaching saturation, possibly taking several hundred years to reach saturation at low deposition rates.

Temporal variations in climate are also important to N effects on soil acidification. During dry periods, much of the N and S ~~deposited~~ remains in soils and vegetation. With adequate aeration, these substances are oxidized and cause runoff during the following rainy period to be extremely acid (114). Likewise, fluctuations between periods of warm, dry years and cool, moist years can induce acidification incidents due to mineralization surges associated with warmer temperatures (85).

H. Sulfur Chemistry

Anthropogenic S emissions and the effects of elevated atmospheric S has become a key focal point for ecological research on the acidic deposition issue. Although N contributes significantly to acidic deposition, S deposition impacts and S cycling have received a greater emphasis in acidic deposition studies to date. Much of the impetus for this concern is due to (a) anthropogenic sources accounting for the majority, roughly 90 percent in the northeastern United States (4), of the S in the atmosphere, (b) the rare occurrence of S deficiencies in forest ecosystems, (c) the marked ability of some forest soils to accumulate S, and (d) the significant impact of soil solution SO_4^{2-} on cation mobility. Mollitor and Berg (34) felt that current SO_4^{2-} inputs to Adirondack forests pose a real threat to the nutrient status of those ecosystems. Their work showed SO_4^{2-} to be extremely mobile in soil solutions and directly related to the leaching losses of basic cations from soil profiles.

The potential benefits of excess S are not clear. Some evidence exists to suggest the close relationship between S and N in plant protein synthesis may cause atmospheric S inputs to benefit N fertilized forest sites. This could arise where rapid soil S utilization due to N fertilizer additions resulted in S deficiencies for some soils. Moderate S inputs due to acidic deposition could benefit these N-amended woodlands (49,118). Excess SO_4^{2-} may also aid in change balances with regard to plant uptake of cationic nutrients (e.g. NH_4^+). The uptake of

SO_4^{2-} by tree roots could reduce the root release of protons into the soil solution (4,118), decreasing internal acid production for the ecosystem.

Wolt and Lietzke (119) examined soils of the Copper Basin area in southeastern Tennessee to evaluate the effects of various levels of acid-sulfate input. Using sites at low, medium, and high intensities of S input downwind from the original smelter operations, they found greater S deposition resulted in decreased soil pH, increased exchangeable acidity, and greater effective cation exchange capacity. Anthropogenic S inputs were not related to changes in exchangeable bases or base saturation.

These workers found some mineralogical evidence indicating greater S inputs resulted in the destruction of gibbsite and the weathering of K-mica to kaolinite. They also proposed that secondary sulfate mineral formation could increase the acid buffering capacity of these soils by the dissolution of hydroxy-Al and the formation of an Al-hydroxy-sulfate compound. Ulrich (76) discussed a similar mechanism. Wolt and Lietzke (119) postulated that the reaction could result in alunite formation by the thermodynamically feasible reaction,

$$2KAl_3Si_3O_{10}(OH)_2 + Al(OH)_3 + 2H_2SO_4 + H^+ + H_2O =$$
$$2Al_2Si_2O_5(OH)_4 + KAl_3(OH)_6(SO_4)_2 + 2SiO_2 + K^+.$$

Recent publications by Johnson and coworkers (49,87) have highlighted the important distinction which exists between the processes of soil acidification and cation leaching in soils. Although both processes may occur simultaneously as a result of acidic deposition, each process can also result from independent soil phenomena. Soils may adsorb both H^+ and SO_4^{2-} which would increase permanent cation exchange capacity, and therefore decrease pH, base saturation, and pH-dependent cation exchange capacity, yet have no effect on net cationic nutrient losses. Similarly, soil organic matter humification increases the soil exchange capacity but does not contribute to cation content. Thus it is feasible that soil acidification could occur without increased losses of bases by leaching.

On the other hand, acidic deposition may increase base cation release due to an acid-induced accelerated rate of mineral weathering. This source of cations could effectively offset any declines in base saturation or pH. The result would be accelerated cationic leaching without a simultaneous acidification of the soil.

Dillon et al. (120) measured the input and output of elements for 11 lakes and 35 watersheds in Sudbury and Muskoka-Haliburton, Ontario in Canada. Their results and observations suggest SO_4^{2-} precursors and strong acid inputs measured by bulk precipitation samplers (i.e. by collection in continuously open containers) underestimated total inputs. They concluded deposition of SO_2 was the most likely explanation for the discrepancies in element balances.

Kelley and Johnson (173) treated loblolly pine seedlings with N and S additions in a greenhouse pot experiment using a Typic Hapludult soil from Tennessee. They found that mixing and warming the study soil greatly increased availability by stimulating S mineralization. It was stated that intensive site preparation in the field has much the same effect on soil and may have analogous consequences on S availability.

Lee et al. (121) used open-top field chambers to treat agricultural soils with various levels of SO_2 to examine the effects of this form of atmospheric S inputs on soil acidification and exchangeable Al content. Ambient conditions were 0.002 ppm SO_2 in the atmosphere with a soil pH of 5.63 and trace amounts of exchangeable Al. Increased SO_2 treatment levels induced simultaneous increases in exchangeable soil Al. Soil pH decreased significantly only after exposure to the 0.24 ppm treatment. The concentration of SO_2 in treatments revealed a significant, linear, and positive correlation with soil SO_4^{2-} levels.

Johnson and Henderson (122) conducted a laboratory study to examine the hypothesis that SO_4^{2-} accumulating in forest ecosystems established on highly weathered soils was due to soil SO_4^{2-} adsorption. Although high levels of adsorbed SO_4^{2-} were detected, further SO_4^{2-} adsorption could not be induced.

Subsequent research on the same soil series was conducted by Johnson et al. (123) utilizing (a) soil samples beneath and adjacent to an old house, (b) lysimeter studies, and (c) SO_4^{2-} salt applications. They concluded from these investigations that SO_4^{2-} had accumulated, was accumulating, and would continue to accumulate in the Fullerton series soil on Walker Branch Watershed. Critical unresolved questions identified in their conclusions were: (a) Why did laboratory and field results differ? (b) How long can those soils continue to accumulate SO_4? and (c) If atmospheric S inputs were reduced, would the adsorbed insoluble pool of SO_4^{2-} become soluble?

Johnson et al. (114) recently synthesized the results from much of the work done on S cycling in the Walker Branch Watershed hardwood forest. These studies indicate that the soil compartment has the largest pool of total S, with available forms far in excess of tree S requirements. Total S input was estimated as 25 to 30 kg S ha^{-1} yr^{-1} with roughly 50 percent attributable to dry deposition. Of the total S input to the forest floor (38.6 kg ha^{-1} yr^{-1}), 73 percent was in solution and 80 percent was soluble SO_4^{2-}. The entire ecosystem was accumulating 15 to 17 kg S ha^{-1} yr^{-1} with only about 2 kg ha^{-1} yr^{-1} attributable to the vegetation component. Most of the annual S accumulation (and 90 percent) was due to mineral soil adsorption in Fe and Al oxide-rich B horizons. They concluded that the S cycle in this forested ecosystem was dominated by geochemical processes.

Singh et al. (124) treated forest soils of southern Norway with simulated acid rain to examine SO_4^{2-} mobility. It was found that SO_4^{2-} mobility was determined by the soil sesquioxide content, and specifically the Al content for the soils studied. The authors suggested S accumulation in soils may, by specific adsorption of SO_4^{2-}, increase cation exchange capacity and promote the retention of cations.

Although much of the concern has been for inorganic SO_4^{2-} in soil chemical investigations regarding S, David et al. (168) found that organically bound S averaged 93 percent of the total S pool in a Beckett soil from the Huntington Forest in the Adirondack Mountains of New York. In this study they measured total S, carbon-bonded S, ester-SO_4^{2-}, and inorganic SO_4^{2-} in the O1, O2, A2, B21h, B22hir, B3, and C1X horizons for soils supporting both hardwood and conifer forests. The highest SO_4^{2-} levels were found in B22hir and B23 horizons, with the softwood site having greater SO_4^{2-} than was detected from the hardwood site. Carbon-bonded S was the dominant organic form of S, averaging 74 percent of total soil S. Both organic and carbon-bonded S decreased with depth in the profile. Ester SO_4^{2-} averaged 18 percent of total S and showed no significant change with depth. The authors stressed the importance of considering organic S in future research with particular concern for S transformations in forest soils.

Mitchell et al. (125) pointed out that deposition, soil sorption capacity, leaching, oxidation-reduction potential (Eh), pH and decomposition are processes affecting S fluxes and transformations between organic and inorganic forms of terrestrial and aquatic ecosystems. They suggested that monitoring S fluxes and transformations may provide an index to the acidification process in these ecosystems.

David et al. (168) pointed out that organically combined S constituted an average of 93 percent of the total S in Adirondack forest soils. The authors stressed the importance of recognizing other S fractions in soils besides SO_4^{2-} with regard to ecological studies.

I Aluminum Chemistry

The role of Al in the chemistry of soils has been the subject of extensive research during the last century. Most of this work was done by plant and soil scientists in an attempt to understand and improve fertilization and liming practices on agricultural croplands (126). More recently, efforts to evaluate nutrient cycles in forested ecosystems, and specifically the relationship between soil chemistry and tree nutrition, have revealed the significance of Al in forest soil solutions. Due in part to the climate, type of vegatative cover, and limited management practices on forested landscapes, soils supporting these plant communities are commonly acid. It is well known that the predominance of Al in soil chemical phenomena increases with increased soil acidity. Research designed to evaluate the impacts of acidic deposition on forested ecosystems has begun to reveal the important role played by Al in observed and potential ecological phenomena. Increased Al activity can be an indirect consequence of acidic deposition-induced environmental changes. However, elevated Al levels in soils, soil solutions, and freshwater environments can have direct, toxic consequences for the biological community (e.g. tree roots, soil microorganisms, and aquatic biota)(127).

The form and activity of Al in aqueous solutions is extremely sensitive to pH variations. The Al ion in solution is surrounded by six water molecules which undergo a series of stepwise hydrolysis reactions as a function of pH. Lindsay (128) showed the reaction series to be:

$$\begin{aligned}
Al(H_2O)_6{}^{3+} &\rightleftharpoons Al(H_2O)_5(OH)^{2+} + H^+\\
&\rightleftharpoons Al(H_2O)_4(OH)_2{}^{+} + 2H^+\\
&\rightleftharpoons Al(H_2O)_3(OH)_3{}^{0} + 3H^+\\
&\rightleftharpoons Al(H_2O)_2(OH)_4{}^{-} + 4H^+\\
&\rightleftharpoons Al(H_2O)_1(OH)_5{}^{2-} + 5H^+
\end{aligned}$$

This series represents a simple Al-H_2O system but points out a mechanism by which Al can buffer soil solutions to changes in pH. Increased H^+ inputs may not result in a pH decline but rather an increase in the ionic change of Al, often coinciding with an increased mobility for this element.

Buffering of H^+ inputs from acidic deposition may also involve the formation of a new Al compound containing S due to the greater concentrations of S in acidic deposition-impacted soils. Wolt and Lietzke (119) suggested the formation of alunite, $KAl_3(OH)_6(SO_4)_2$, by the reaction described earlier in the Sulfur Chemistry section. Ulrich et al. (76) considered the reaction, $AlOOH + 2H^+ + SO_4{}^{2-} \rightleftharpoons \overline{AlOH}SO_4 + H_2O$, to be responsible for soil buffering along with the production of Al ions.

The rate of reaction between soil Al and acid inputs is dependent on the fraction of Al with which these atmospheric inputs react. Table 1 illustrates the various soil Al fractions and their reaction rates with H_2SO_4 as presented by Cronan (129). For solutions percolating through soils with limited residence time in the solum, the first three Al fractions play the primary role in Al release.

TABLE 1

SOIL ALUMINUM FRACTIONS WHICH MAY RELEASE INORGANIC ALUMINUM TO THE SOIL SOLUTION IN FORESTED ECOSYSTEMS EXPOSED TO ACID PRECIPITATION

Aluminum Fraction*	Reaction Rate with H_2SO_4
Exchangeable aluminum	Rapid
Amorphous aluminum hydroxide	Moderately rapid
Organic-aluminum complexes	Moderately rapid
$Al_x(OH)_y$ interlayers in expansible clay minerals (e.g. vermiculite)	Relatively slower
Aluminum in clay lattices	Relatively slower
Undecomposed aluminum silicates	Relatively slower

*The fractions are ranked according to their hypothesized ability to release dissolved aluminum to a H_2SO_4-dominated soil solution.

In studies where simulated acid rain treatments were applied to soil microcosms, Cronan (79) found increased treatment acidity resulted in greater Ca^{2+}, Mg^{2+}, K^+, and NH_4^+ leaching but Al losses did not increase. He postulated that lack of increased Al reflected a kinetic lag which occurred in the mobilization of this element.

McFee and Cronan (130) and Cronan (129) discussed evidence suggesting an alteration of Al chemistry has occurred in podzolized forest soils leached by atmospheric H_2SO_4 inputs. For most soils subjected to podzolization, a soil weathering process, Al and other metals undergo solution and organometallic complexation in the surface horizons. These materials leach downward with one result being the transport and accumulation of Al into the B2 soil horizon due to changes in the soil chemical environment with depth in the profile. This mechanism effectively removes Al from solution such that very little is detected in groundwater supplies. By contrast, it appears that acidic deposition-impacted, podzolic soils show a continuous increase in dissolved Al concentration as water percolates through the profile, which is ultimately reflected as elevated Al in groundwater. They suggested possible causes for these results could be (a) a small but significant decrease in soil solution pH throughout the profile which increases Al mobility, or (b) whereas organic acid acidity is removed from solution by other mechanisms, mineral acid neutralization may be primarily controlled by H^+-ion exchange and weathering reactions which are not kinetically or thermodynamically favored in acid soils leached with solutions of pH 4 or 4.5.

McFee and Cronan (130) also pointed out an important distinction between "acidic deposition" and "soil acidification". The first term describes the atmospheric input of acids, acid precursors, and associated substances to the earth's surface. The second term describes a process which is always occurring in soils of humid regions, regardless of the level of acidic substances in the atmosphere.

Soil acidification is a naturally occurring process in the vast majority of forest soils. The sum total acidifying effect of natural pedogenetic processes in humid climates probably far exceeds the effects of acidic deposition alone. What needs to be determined is whether "acidic deposition" contributes a significant increment toward increasing natural "soil acidification" processes.

The recent research on Al chemistry discussed above provides some insight into the previously discussed two-step process of 'acid rain' neutralization in a Hubbard Brook watershed proposed by Johnson et al. (106). In this process, H^+-ion acidity is neutralized by soil aluminum which is the dominant mechanism in the upper reaches of the stream. Streamwater acidity and inorganic monomeric Al decreased, while organically complexed Al increased steadily in a downstream direction. They pointed out that earlier studies at Hubbard Brook showed the humus layer and B2 soil horizons to be the primary source of Al for acid waters percolating through the soil.

In a recent paper, Stottlemeyer (131) reported a rapid neutralization of acid precipitation (weighted mean pH ranged 3.87 to 4.88) in the upper reaches of a watershed in northern Michigan. Very little Al was detected in these streamwaters with pH values averaging 6.0 to 7.0; however, one acid rain event caused the pH to drop to 5.5, which also showed a sharply increased Al level in streamwater.

With regard to forest productivity, the concern for elevated levels of soil solution Al center around the toxic effects of this element on soil microorganisms and tree roots (84). Detrimental effects on soil microorganisms are evident in decreased rates of organic matter decomposition, while trees may show foliar damage and mortality. Matzner and Ulrich (132) pointed out the importance of the Ca/Al molar ratio in soil solutions. They also reported that soil solution Al concentrations in the Solling forestlands have increased over the last decade. Concentrations of Al in soil solutions from beech stands roughly have doubled (from 1 to 2 mg/l to 2 to 5 mg/l) while beneath spruce there has been nearly a tenfold increase (from 1-2 mg/l to 15-18 mg/l). Ulrich (84) stated that below pH 4.2 in soil solutions, even Al-tolerant tree species may show toxicity symptoms. The degree of toxicity below this pH depends on the Ca/Al molar ratio and the presence of dissolved organic material available to chelate Al ions. When the Ca/Al molar ratio is below 1.0, Al toxicity is thought to become a problem. Complete growth inhibition occurs below Ca/Al molar ratios of 0.15 in soil solution.

Ulrich (84) stated that Al ions in the soil solution may damage the endodermis in tree roots, the result being the loss of control over the ionic composition of the solution entering the plant's xylary vessels. Plants cannot separate damaged from undamaged roots, nor can they originate new roots from the undamaged parts under these conditions. He listed the possible consequences of this condition as (a) secondary diseases originating from pathogen spore transport into the xylem, (b) damage by root decomposing fungi increasing the windthrow hazard, (c) nutrient deficiencies due to lack of control over ionic composition of transpiration stream, (d) decreased production of secondary plant substances which inhibit insect and fungi attack, and (e) reduced buffering ability to acid inputs by leaf and bark surfaces. Increased susceptibility to drought stress also results from damage to root systems.

VIII RESEARCH RELATED TO THE EVALUATION OF FOREST SOIL SENSITIVITY TO ACIDIC DEPOSITION

An information need which has emerged as being of imminent practical importance in addressing the acidic deposition issue is the evaluation of ecosystem sensitivity to atmospheric inputs. Much of the work done in this area has examined the sensitivity of either (a) plants, (b) soils, (c) bedrock, or (d) aquatic ecosystems. With regard to forest productivity, sensitivity to acidic deposition can be approached either as direct impacts on vegetation or impacts on forest productivity due to soil-mediated interactions. Current knowledge on forest effects has shown soil-mediated interactions to be a key component to sensitivity assessment for acidic deposition. The reader is referred to the 1978 NATO conference proceedings (17) for a collection of papers by highly respected soil scientists involved in this area of acidic deposition research.

One of the most important points to consider in dealing with research on the sensitivity of forest soils to acidic deposition is the definition of "sensitivity" which underlies the overall program presented. Forest soil sensitivity may be considered from various viewpoints producing differing results in the properties considered critical. Forest soil sensitivity to acidic deposition can be assessed, for example, in regard to alterations in (a) forest productivity, (b) the leaching rate of basic cations, (c) soil acidification or the loss in ability to neutralize acids, and (d) soil-mediated inputs to aquatic ecosystems.

The recent conference of an international group of experts on the soil acidification issue which was convened in Sweden to assess the current state of knowledge on acidic deposition, in their final report (8), cited sandy, well drained soils of pH 5 to pH 6 as being most susceptible to acidification. They defined acidification as a loss of neutralizing capacity by the soil. In regard to forest ecosystems, they believed the greatest risk was for forests on thin, silty or sandy acidic soils overlying non-calcareous bedrock.

Wiklander (174) defined soil acidification as a decrease in pH and base saturation due to internal and external H^+ ion sources.

Bache (133) felt that highly unsaturated, acidic soils were most susceptible to further acidification but occurred in areas where this would not result. He stated, however, that slightly acid, poorly buffered, shallow sandy soils may show a striking loss in productivity, particularly for forested areas, with relatively little acidification.

In some cases, the assessment of ecosystem sensitivity to acidic deposition may be highly correlated to bedrock properties. Shilts (134) has prepared an assessment of the sensitivity of Canadian bedrock types to acid precipitation. Hendry et al. (135) looked at the sensitivity of bedrock types in the eastern United States. In their classification scheme for the

United States, sensitivity was evaluated based on the percent of highly alkaline rock types underlying the area.

With regard to tree growth, geologic ratings for acidic deposition sensitvity may often be inadequate. Tree roots permeate the upper zone of the regolith and are more directly affected by the physical and chemical properties of forest soils. For soils developing from glacial, alluvial, lacustrine, marine, or aeolian parent materials, bedrock geology information may provide little indication as to the properties of the overlying soil material. Even within the solum, the genesis of distinct horizon sequences can offer complex problems for the classification of these materials, particularly with regard to acidic deposition sensitivity.

McFee (136) developed a set of criteria to rank soil sensitivity to the effects of acid precipitation. His scheme is based on the cation exchange capacity of soils, flooding occurrence, and the presence or absence of carbonates in the top 25 cm of soil. Soil sensitivity was evaluated with respect to "....any change brought about by acid precipitation that would be important in the local ecosystem." Three sensitivity groups were designated.

(1) Non-sensitive areas: Soils which are calcareous, subject to frequent flooding, or have an average cation exchange capacity of greater than 15.4 meq/100 g in the top 25 cm.

(2) Slightly sensitive areas: Soils with a cation exchange capacity between 15.4 to 6.2 meq/100 g in the top 25 cm.

(3) Sensitive areas: Soils with a cation exchange capacity less than 6.2 meq/100 g in the top 25 cm.

This model is one of the most frequently cited efforts to date which delineates soils information in this country with respect to acidic deposition. A primary advantage of this type of classification is the availability of the necessary soils information. The major disadvantages are (a) it is too general for detailed site-specific analyses, and (b) as McFee himself admits, the use of cation exchange capacity alone without base saturation may not be adequate to appraise soil sensitivity. McFee and Cronan (130) also pointed out this system fails to consider soil sulfate adsorption capacity, the presence of easily weatherable minerals, or differences between low cation exchange capacity soils.

Glass et al. (33) discussed the sensitivity of crops, soils, forests, rock formations, and surface waters to acid precipitation, using New York State as an example in their analysis. They utilized McFee's (136) classification system to rate the soils of New York state to acidic deposition sensitivity and found sensitive areas to be concentrated in the Adirondack region, east of the Hudson River, and on Long Island. In addition to the properties suggested by McFee (136) and McFee and Cronan (130), they also added the need for information on soil physical characteristics and climate in the analysis.

Gibson and Lindhurst (26) suggested that research shows soils likely to undergo significant changes in basic cation composition due to acid inputs were: (a) not renewed by flooding or other processes, (b)free of carbonates to a considerable depth, (c)low in cation exchange capacity but have pH values between 5.5 to 6.0 or higher, and (d) not high in sulfate adsorption capacity.

Because most humid climate soils would have lower pH values than 5.5 to 6.0, they believed short-term effects to forest productivity by nutrient losses were unlikely. However, the effects of elevated soil solution Al in acidic soils were considered to be the most likely problem for impacted forest ecosystems.

Regardless of the intent of a classification for forest soil sensitivity, the chemical interaction between incoming precipitation and the soil matrix depends on the initial composition of these components. Ulrich (16,83,137) has described a series of soil buffering ranges which were delineated by soil pH. This classification can be summarized as:

(1) pH 6.5 to 8.3 - Carbonate Buffering Range: soil buffering of incoming H^+ primarily due to the dissolution of $CaCO_3$,

(2) pH 5.0 to 6.5 - Silicate Neutralization Range: soil buffering of incoming H^+ due to the dissolution of silicate minerals,

(3) pH 4.2 to 5.0 - Cation Exchange Neutralization Range: soil buffering of incoming H^+ due to the displacement of bases (e.g. Ca^{2+}, Mg^{2+}) by H^+ (and sometimes by dissolved Al ions due to the H^+ input) from the soil exchange complex,

(4) pH 3.0 to 4.2 - Aluminum Buffering Range: soil buffering of incoming H^+ due to the release of Al^{3+} primarily from soil polymeric hydroxy Al compounds, and

(5) pH below 3.0 - Iron Buffering Range: soil buffering of incoming H^+ due to the formation of Fe ions by release from Fe-oxides.

The dominant soil neutralization mechanism will remain in a steady state as long as the rate of H^+ deposition equals the rate of neutralization. Once the H^+ deposition rate exceeds the rate of neutralization, the dominant mechanism of soil buffering will shift to the next lower pH range.

Klopatek *et al.* (138) developed a sensitivity rating to acidic deposition for soils in the eastern United States based on pH, cation exchange capacity, and base saturation. Base content was calculated as the product of cation exchange capacity and base saturation which provided an index to the base reserves in the soil. Soils of low cation exchange capacity and pH values greater than 5.0 were considered most susceptible to further acidification. Soils already acid were considered critical with respect to the impact on associated freshwater systems due to acidic deposition. This model is similar yet somewhat more comprehensive than McFee's. However, it differs with respect to the mechanics of the computations and therefore direct comparison between the systems is difficult.

A great deal of work has been done in Canada to assess soil sensitivity to acidic deposition. Wang and Coote (139) and Coote *et al.* (140) classified soil sensitivity to acidic deposition for agricultural land in eastern Canada. Their emphasis was on developing a system simple enough to use in the field. Utilizing the relationships between soil base saturation with soil pH, and soil texture with cation exchange capacity, they arrived at three sensitivity classes.

(1)	*Nonsensitive:*	All calcareous soils Clayey with pH below 5.0 Loamy with pH below 5.5
(2)	*Moderately Sensitive:*	Sandy with pH below 5.5 Clayey with pH 4.5 to 5.0 Loamy with pH 5.0 to 5.5
(3)	*Sensitive:*	Clayey with pH below 4.5 Loamy with pH below 5.0 Sandy with pH below 5.5

This rating is for the upper 15 cm of unlimed soil.

Cowell *et al.* (141) developed an ecological rating system to evaluate the effects of acid rain on the terrestrial environment of eastern North America. Their classification system recognized different factors which need to be considered when determining the effects of acidic deposition on forest soils with respect to (a) forest productivity versus (b) soil-mediated aquatic impacts. *Table 2* by Cowell *et al.* illustrates the factors considered important by these authors in evaluating forest

TABLE 2. FOREST PRODUCTIVITY SENSITIVITY

Terrestrial Factors	Sensitivity		
	Low	Moderate	High
Soil Chemistry			
i) Exchangeable Bases	>15 meq/100g	6 to 15 meq/100g	<6 meq/100g
Surrogate: Combinations of pH in water (or % Base Saturation) and one of (a) Family Particle Size	clayey, >pH 5.0 loamy, >pH 5.5 all calcareous soils	clayey, pH 4.5 to 5.0 loamy, pH 5.0 to 5.5 sandy, >pH 5.5	clayey, <pH 4.5 loamy, <pH 5.0 sandy, <pH 5.5
or (b) Texture	clay, silty clay, sandy clay (>35% clay)	silty clay loam, clay loam, sandy clay loam, silt loam, loam (10 to 35% clay)	silt, sandy loam, loamy sand, sand (<10% clay)
or (c) Cation Exchange Capacity	>25 meq/100g	10 to 25 meq/100 g	<10 meq/100 gr
ii) SO_4^{2-} Adsorption Capacity as determined by:	low organic matter AND high Al_2O_3 and/or $Fe_2O_3 + Fe_3O_4$	———	high organic matter AND low Al_2O_3 and/or $Fe_2O_3 + Fe_3O_4$
Soil Depth*	>25 cm	>25 cm	<25 cm*
* If soil depth is less than 25 cm, Underlying Material is incorporated			
Underlying Material			
i) Parent Material	carbonate bearing	non-carbonate bearing	non-carbonate bearing
ii) Bedrock Material	limestone, dolomite, and metamorphic equivalents, calcarous clastic rocks, carbonate rocks inter-interbedded with non-carbonate rocks	volcanic rocks, shales, greywackes, sandstones, ultramafic rocks, gabbro, mudstone, meta-equivalents	granite, granite gneiss, orthoquartzite, syenite

From Cowell *et al*. (141)

soil sensitivity to acidic deposition, specifically in relation to forest productivity. They considered low pH soils (i.e. less than pH 4.5) were most sensitive in this regard since any further loss of cations would be significant to forest growth. Rubec (142) published information on the characteristics of acidic deposition-impacted areas in Canada with computer summaries of the data as part of the Canadian effort to classify the sensitivity of natural ecosystems.

Johnson (93) discussed the theoretical impact of increased acidic deposition on groundwaters and soil solutions for selected Alaskan sites. He concluded those solutions already acid were most susceptible to further acidification, the reason being H^+ constitutes a much higher proportion of the total cations in the more acid solutions and will therefore be more likely to accompany the SO_4^{2-} anion in solution. Johnson (175) also discussed the importance of soil SO_4^{2-} adsorption capacity and sesquioxide content in assessing H_2SO_4 impacts on cation leaching processes.

Johnson et al. (49) discussed the differences between forest soil sensitivity to cation leaching by H_2SO_4 and HNO_3 inputs. According to the anion mobility concept, the major factor influencing the base cation leaching loss in soils is the mobility of the associated anion in soil solution. These authors suggested sites sensitive to leaching by H_2SO_4 are low in Fe and Al oxides and clay, but high in pH and organic matter content. These properties lead to less adsorption of SO_4^{2-} by the soil, resulting in greater cation leaching losses. Johnson and Todd (143) recently discussed methods and applications for soil SO_4^{2-} adsorption analysis. As for sites sensitive to HNO_3 leaching losses, soils with adequate available N for tree growth would cause very little of the atmospheric N to be taken up, resulting in HNO_3 leaching losses being greater from N-abundant forest sites (49).

Troedsson and Nilsson (144) applied forest soil sensitivity information to the evaluation of areas suitable for the siting of coal-fired power plants in Sweden. They considered the sensitivity of soils for increased acidification to be a function of (a) the use of the land in question (e.g. deciduous versus coniferous forest soils, (b) the texture of the soil, (c) the thickness of the soil layer, (d) hydrological conditions, (e) mineralogical properties, including soil type, and (f) chemical properties.

IX IMPLICATIONS OF ACIDIC DEPOSITION IMPACTS IN FOREST MANAGEMENT DECISIONS

Without question, the activities of man play a major role in shaping the character of modern forests. Decisions concerning the treatment of commercial timberlands by forest management should be made with the best knowledge of probable outcomes. Acidic deposition impacts should be an additional factor considered when evaluating potential silvicultural prescriptions in light of several important interactions between deposition inputs and treatments which are possible. This area of acidic deposition research is almost completely unexplored at present, with the available information primarily theoretical in nature. It may be important, however, to consider the most significant potential interactions between acidic deposition and management decisions for the sake of future forests.

Acidic deposition may increase the effects of some treatments while decreasing others. These interactions most likely are highly dependent on specific site conditions. Common forest practices which may be influenced by acidic deposition considerations include (a) site preparation, (b) forest fertilization, (c) species selection, (d) intermediate cuttings, and (e) harvesting systems. It is also possible that decisions regarding land acquisition and sales may benefit from consideration of acidic deposition effects.

A. Forest Fertilization

Since the impact of acidic deposition on forests largely is a biogeochemical phenonemenon, forest fertilization is a major area of management activity potentially affected by acidic deposition. In Sweden, forest fertilization activity is expected to increase, and ammonium nitrate (NH_4NO_3) is presently the most common fertilizer used (169). Repeated fertilization with this material can lead to excessive base leaching losses due to the NO_3^- anion, with eventual acidification of the soil. Earlier, urea was used and over the long run appeared to have little effect on soil acidity. Johnson et al. (49) pointed out that N fertilization is known to immobilize free SO_4^{2-} in foliage which could improve the resistance of trees to direct effects of acid rain.

Khanna and Ulrich (145) treated beech and spruce stands with KCl and NH_4NO_3 fertilizers in the Solling forests of West Germany. Fertilization was shown to increase the total amount of N and K in beech foliage. Beech throughfall exhibited greater total N and K^+ with lower H^+. These effects were not evident for spruce throughfall. The results indicate a need to consider both the species and its interaction with management practices when evaluating forest effects of acidic deposition.

Ulrich (146) presented a theoretical treatment of forest fertilization in light of the German experience with acidic deposition. Referring to the five soil buffer ranges Ulrich has delineated, which were discussed in the soil sensitivity section, he believes soils are optimum for tree growth in the silicate buffer range (pH 5.0 to 6.5). Under these conditions (a) cations released by weathering are bound as exchangeable (b) almost no NO_3^- is lost, (c) there is little gradient in chemical properties with depth (as in $CaCO_3$ buffer range soils), and (d) forest ecosystems remaining continuously in this buffer range are stable and need no fertilization. In the cation exchange buffer range (pH 4.2 to 5.0) Al becomes important on the exchange complex and a "mor" forest floor may develop, indicating the N cycle is not closed and nutrients are tied up in the litter. Under these conditions fertilization may increase phytomass production and forest yield. The use of fertilizers consisting of easily soluble salts is considered undesirable due to the well known effect of dilute salt solutions in depressing solution pH. This is particularly the case in the Al and Fe buffer ranges (below pH 4.2).

Ulrich pointed out that acidic deposition is a major factor affecting the dominant buffer range for forest soils. Due to Ulrich's model for an acidic deposition-induced "discoupling" of the ion cycles in forests, organic matter passes through phases of accumulation and decomposition during cool, humid or warm, dry periods, respectively. The decomposition phase causes an acid surge due to nitrification and HNO_3 production; therefore he feels fertilization additions must be coordinated with natural acidification cycles. Positive effects of fertilization are restricted to soils in the cation exchange buffer range, not undergoing a period of humus disintegration. At this time N is abundant and additions would only increase base leaching losses. During a deacidification phase in this buffer range the opposite is true and fertilization would correct deficiencies. Additions of lime should be restricted to cation exchange buffer range soils in a decomposition phase to decrease the acid surge effects.

B. Species Conversion

Attention has recently been given to the possibility that opportunities exist for reducing potential negative impacts of acidic deposition through the use of specific tree species. Troedsson (147) recently evaluated data on pure and mixed stands of birch and spruce in Sweden to see what possibility might exist for species selection in preventing further forest soil acidification due to air pollution. Due to climatic conditions, birch was considered the only relevant broadleafed species for Sweden. They concluded it was unlikely that replacing spruce or pine with birch would decrease soil acidification unless site index was high. At high site index locations, however, volume production by birch is half that of spruce. For birch to be effective in increasing soil pH the author concluded it would have to comprise at least 50 to 60 percent of a mixed stand.

Research has indicated that for some cases, a complete switch from spruce to birch could raise the humus layer pH by 0.2 to 0.4 units (169). It was suggested that any evaluation of the merits for increasing birch percentage in forests should be evaluated relative to the cost of liming to achieve equivalent soil pH increases.

Johnson et al. (49) pointed out that the common practice in the United States of converting from deciduous to coniferous species may actually decrease the overall impact of acidic deposition on forest nutrition. They reasoned that (a) conifers have a lower nutrient demand on the site, and (b) conifers acidify the site themselves and may be more tolerant of acid inputs. It was also pointed out that acid precipitation may accelerate soil acidification in coniferous stands.

C. Harvesting Operations

Both acidic deposition and the harvesting of forest growth are fctors important in assessing the net export of elements from the forest ecosystem. Conclusions from the recent Swedish conference on acidic deposition (8,169) urged restraint in the use of whole-tree harvesting practices on sensitive soils. Under these conditions, whole-tree utilization can increase the acidifying increment two to three times when compared to conventional forestry practices. They pointed out that both increased acidification and long-term forest production consequences are possible.

Ulrich (85) suggested that modern forestry practices limiting the use of wood to trunks and branches greater than 7 cm in diameter has contributed significantly to the recovery of forests from acidic deposition. However, he also stated that forestry itself has triggered acidification incidents by practices such as planting only tree species with litter resistant to decomposition (i.e. spruce, pine, larch).

D. Changes in Land Use Patterns

Nilssen et al. (170) calculated the contribution of root H^+ production to the overall acidification process in soils and compared this to acidic deposition inputs. The critical factors which were considered important in comparing these two

H^+ sources were (a) the pattern of introduction, (b) the location at which it is introduced, and (c) the presence, or otherwise, of an accompanying mobile anion. Precipitation H^+ inputs tend to be episodic, which causes concentrated, short-term H^+ inputs to move in runoff or through soil channels and rapidly drain from the soil. The H^+ produced by roots, however, is intimately associated with soil exchange sites and would more likely interact chemically with soil particles. Also, root H^+ release can be accompanied by cation uptake involving no anion movement. Acid precipitation, on the other hand, contributes a highly mobile anion which accompanies the H^+ in solution. The net result of these factors was outlined as (a) the possible dominance of H^+ in polluted rain causing freshwater acidification whereas (b) biological H^+ production dominated soil acidifying processes.

Krug (148) presented a hypothesis that changes in land use since the mid-1920's may be responsible for the increased acidity in runoff from mountainous watersheds. He pointed out that the extensive timber harvesting practiced before the 1920's time period has declined, leading to the aggradation of forest lands. Accompanying this change in land use is the development of acid, humus soils. The development of acid conditions in mountainous areas of thin soil mantles has caused a decline in the soil's acid neutralizing ability for these areas, resulting in the observed acid runoff.

Other studies have also looked at the effect of land use on ecosystem chemistry and found forestry often related to greater levls of acidifying inputs than other uses (149). Rosenqvist _et al_. (150) indicated the high acidity from the raw humus in heather, spruce, and moss dominated areas was far more important to surface water acidification than modern Norwegian pollutants.

X EXTENT OF PRECIPITATION MONITORING NETWORKS

One of the most important information needs which was identified early on by all parties concerned with the acidic deposition issue was data describing the quantitative, qualitative, temporal, and spatial characteristics of atmospheric deposition. It is essential to have long-term monitoring of deposition inputs in order to accurately assess trends in atmospheric chemistry and effects on terrestrial and aquatic ecosystems. Details of national and international deposition monitoring networks are included in _Appendix A_.

The National Acid Precipitation Assessment Plan (NAPAP) prepared by the federal Interagency Task Force on Acid Precipitation (ITFAP) has designated the Department of the Interior

(DOI) to carry out its goals for deposition monitoring. These activities are to include development of (a) the Global Trends Network (GTN), and (b) the National Trends Network (NTN).

Development of the GTN will be carried out by evaluating the current worldwide deposition monitoring network operated by the World Meteorological Organization (WMO) as to number and location of sites. Modifications will be made as needed, in conformity with WMO requirements, to assure adequate geographical coverage. The operation of the GTN will be coordinated with the NTN so data collected by both networks will be compatible.

The NTN will be developed to monitor deposition in the United States. Due to the highly organized deposition monitoring activities carried out by the National Acid Deposition Program (NADP) under the auspices of the Department of Agriculture (DOA), close coordination is planned between these two overlapping networks. Although many NADP stations will be part of the NTN, each network will maintain its identity and a separate list of sites. Site operator training, sample collection, sample processing, and data handling and storage are activities which NADP will coordinate for both networks.

The NADP has expanded from a regional project (NC-141) to an interregional project (IR-7) under the DOA's Hatch Act program of funding. This will provide for planning, administration, and funding on a national level in line with NADP activities. Funding for the network research (e.g. deposition monitoring) program for FY 1982 was $1,051,500 and is proposed for FY 1983 at $1,267,600. An important part of NADP activities is an emerging program to fund research aimed at evaluating the effects of acidic deposition. This portion of the total program is anticipated to increase from $470,000 for FY 1982 to $1,320,000 for FY 1983.

A large number of monitoring efforts have emerged over the last five years in answer to the need for information on atmospheric deposition. Some programs have merged and standardized procedures in order to provide the most useful, wide range data base possible. Often, however, the specific needs of a monitoring effort demand a unique set of sampling or testing procedures to achieve their objectives.

Wisniewski and Kinsman (178) recently reviewed the current monitoring programs in the United States, Canada, and Mexico. Appendix A provides a summary of descriptive information from this review on the currently active (a) international networks, (b) national United States networks, (c) regional United States networks, (d) national Canadian networks, (e) regional Canadian networks, and (f) national Mexican networks. Deposition monitoring networks at the state level ranging from 1 to 15 stations also exist in Alabama, Arkansas, California, Colorado, Florida, Maryland, Minnesota, New Hampshire, New Jersey, New Mexico, New York, North Dakota, Pennsylvania, South Carolina, Tennessee, Texas, Virginia, Washington,D.C., West Virginia, and Wisconsin, utilizing a variety of methodologies. Canadian provincial networks in Alberta, New Brunswick, Nova Scotia, Ontario, and Quebec range in size from 5 to 45 stations. A number of Canadian monitoring networks exist at the local level also.

The major Canadian monitoring network described in Appendix A, which has been operated in close coordination with the United States NADP network, is the Canadian Network for Sampling Precipitation (CANSAP). As of April 1, 1983 the newly established Canadian Air and Precipitation Monitoring Network (CAPMON) will take precedence over the old CANSAP and will include a total of 50 monitoring stations by the end of the initial eighteen month period. The new system will improve existing data collection and provide for greater standardization. A significant and ambitious aspect of CAPMON will be daily wet deposition collection and analysis for samples from selected sites.

XI EXTENT OF ACIDIC DEPOSITION RESEARCH ACTIVITIES RELATED TO FOREST PRODUCTIVITY

A. Introduction

The exponential growth in publications dealing with acidic deposition impacts on forests and forest soils reflects a paralleled sharp increase in the active research programs in this subject area. Appendix B provides a rather detailed summary of the majority of research activity in the area of acidic deposition impacts on forest productivity and forest ecosystem phenomena in the United States. A deliberate effort was made to present only those studies which provide insight into the forest productivity question. This is, however, an arbitrary distinction as much of the research concentrating on other areas of "effects" research (e.g. crops, aquatic ecosystems, materials) will undoubtedly contribute significantly to our understanding of forest ecosystem response to acidic deposition.

The discussion below seeks to provide an overview of research in this area on an international scale. This information has been gathered through verbal and written communications with universities, private organizations, and government agencies in the United States, Canada, and Europe. All of the universities with forestry programs in the United States, and additional schools identified as active in this area of research, were contacted.

Information on acidic deposition research funded by the private sector was taken in large measure from the recently prepared inventory of privately supported research (152) and reports detailing the Electric Power Research Institute's (EPRI) Acidic Precipitation Research Program.

The National Acid Precipitation Assessment Plan (151) outlines broad research goals for the federal government which have been identified by the Interagency Task Force on Acid Precipitation (ITFAP). The specific technical and programmatic details of the federal program are outlined in the ITFAP's Operational Plan (154). All research in Appendix B which displays an asterisk (*) after the funding source is included in the ITFAP's Operational Plan for Terrestrial Effects which covers the areas of forests and soils. Funding allocations for these studies listed for fiscal year 1982 were administered between October 1981 and October 1982. Funding for fiscal year 1983 are proposed levels and approval is staggered chronologically on an agency-by-agency basis. At the time of this writing, almost all agencies involved in the Terrestrial Impacts Task Group Operational Plan had or were expected to receive approval for the fiscal year 1983 budgets. Funding levels for fiscal year 1984 are proposed.

The following discussion provides a broad overview of acidic deposition activities ongoing in various countries.

B. The United States

A review of the research outlined in Appendix B reveals the tremendous effort being devoted in the United States to the study of acidic deposition impacts on forests and soils. A recently prepared overview of acidic deposition research (153) estimated that the total combined efforts of the federal and private sectors in acidic deposition research totalled $26 million for 1982, a significant increase over 1980 and 1981 totals of approximately $14 and $20 million, respectively. Their conservative estimates for 1983 and 1984 were between $35 and $37 million per year.

It is impossible to segregate funding devoted solely to forest effects without relying on arbitrary decisions regarding the relevance of specific investigation components to the forest productivity issue. For example, forest soils are believed to be critical in the analysis of acidic deposition impacts to both forest and freshwater ecosystems. Nevertheless, the available information on forest-effects related research suggests an estimated $4.5 million was spent in 1982 to examine the direct and indirect effects of acidic deposition on forest productivity. This is roughly three times the estimated $1.5 million spent on forest effects research in 1980 in the United States.

It is also apparent that the 1982 levels will be greatly exceeded in subsequent years due to the continued growth and interest in forest effects research.

At the federal level the key source of research funding and activity is the ITFAP. Funding for the ITFAP Operational Plan was $18 million for 1982 and will be $22 million in 1983. This reveals the rapid expansion of the federal acid precipitation research effort when compared to 1980 and 1981 funding levels of $11 and $13 million, respectively. The Task Group on Terrestrial Effects is directly responsible for forest and soil-related studies. The Coordinating Agency for the Terrestrial Effects Task Group is the Department of Agriculture. Funding for the Terrestrial Impacts component of the 1983 budget is $4.4 million. Periodic assessments are seen as the driving force for the national program, with a timetable in place by which major "deliverables" can be expected. The first major deliverable will be an assessment of damage at ambient levels of deposition in 1985 with cost/benefit analyses due in 1988 to 1989. Federal agencies are also involved in research not included in the national program. EPA has a major cooperative agreement with North Carolina State University to fund key research designed to elucidate the impacts of acidic deposition on aquatic and terrestrial ecosystems.

The private sector, particularly the electric utility industry, has spent approximately $18.7 million over the last three years (1980-1982) on acidic deposition research (152). An estimated 43 percent of this total was devoted to studying environmental effects, the most heavily funded category. A major force in providing support for the research on acidic deposition is the Electric Power Research Institute (EPRI). The most recent description of the EPRI Acidic Deposition Research Program indicates total expenditures of over $16 million through 1982 of which roughly half ($8.8 million) was devoted to ecological effects research. Future EPRI funding averages $13 million per year through 1987, with the ecological effects effort at $4.8, $5.1, $5.9, $6.0 and $7.3 million for 1983, 1984, 1985, 1986 and 1987, respectively.

Other private sector entities involved in acidic deposition research include the forest products industry, the petroleum industry, the motor vehicles industry, environmental interest groups, the coal industry, the metal smelting industry, fishing interest groups and the gas industry.

Acidic deposition research at the state level has been minimal up to the present, but several programs are developing. Wisconsin and California have entered into cooperatively funded programs of research which are referred to in Appendix B by the state agency directly involved. A joint federal, state and private sector effort for research in the Southern Blue Ridge Province region is currently planned which would involve Georgia, North Carolina, South Carolina and Tennessee. The project is being coordinated through the Tennessee Valley Authority.

C. Canada

The Canadian effort to study and define the various scientific aspects of the acidic deposition issue has substantially expanded in the past few years with a great deal of emphasis in the area of forests and soils research. The Federal Government of Canada will spend approximately $42 million (Canadian) between 1980 and 1984 on their Long-Range Transport of Air Pollutants (LRTAP) research program. The agencies involved in this program include the Department of the Environment (DOE), Agriculture Canada (CDA), Engery, Mines and Resources (EMR), Canadian Forestry Service (CFS), Canadian Wildlife Service (CWS) and the Lands Directorate (LD). Work by the CFS makes up a substantial portion of the studies on forests and forest soils.

The provinces also have programs addressing the acidic deposition issue. Ontario has the most extensive program in this area of study with approximately $5 million (Canadian) spent on acidic deposition research annually.

In February of 1981 Environment Canada published an inventory of 328 research projects initiated at that time (155). In order to provide some insight into the nature of the Canadian programs dealing with the effects of acidic deposition on forests and forest soils, Appendix C contains projects listed in the Canadian inventory which (a) have direct bearing on the forest effects subject, and (b) indicated they would be active at least into 1982 or beyond. Without question, some studies not cited may have continued and new programs have been formed. All indicated funding levels are in Canadian dollars.

An important component in the overall terrestrial program is the work being carried out at three catchment basins: (a) the Algoma basin north of of Sault Ste. Marie, representing hard maple on Podzolic/Brunisolic soil found across eastern Canada, (b) the Montmorency basin north of Quebec City, representing the spruce-fir boreal forest on strong Podzol soils found across much of the boreal zone, and (c) the Kejimkujik basin in central Nova Scotia, typifying the Acadian forest.

A developing research program at Muskoka-Haliburton near Dorset, Ontario adds a fourth catchment area of importance in the acidic deposition research program.

Catchment studies include deposition monitoring, vegetative measurements of cover and growth rates, and the development of hydrologic and ionic budgets.

In addition, complementary research is carried out at five CFS Research Centres (at the above catchments plus the Northern Forest Research Centre at Edmonton and the Newfoundland Forest Research Centre at St. John's. These studies include (a) determination of sensitivity of different forest species to acid rain mist, (b) determination of the role of acid rain in physiological, biochemical, nutritional, visual and growth changes, (c) simulation of acid rain in leaching nutrients from soils under natural conditions and in rebuilt soil columns, (d) determination of geographical deposition patterns of heavy metals, and the effects of heavy metals on plants and soils in selected areas, and (e) determination of whether nitrate deposition from NO_x emissions are beneficial or detrimental to tree growth.

D. Norway

One of the first large-scale, coordinated research programs to study the effects of acid precipitation was the Norwegian program entitled "Acid Precipitation - Effects on Forests and Fish" (the SNSF Project). This cooperative program began in 1972 with the termination of research activities in 1979. The program was sponsored by the Norwegian Council for Scientific and Industrial Research, the Agricultural Research Council of Norway, and the Norwegian Ministry of Environment. Approximately fifteen research institutions cooperated on the project which cost over $15 million (US). The objectives of the overall program were to (a) establish as precisely as possible the effects of acid precipitation on forests and freshwater fish, and (b) investigate the effcts of air pollutants on soil, vegetation and water, required to satisfy point (a).

An International Conference was held in March of 1980 in Sandefjord, Norway to povide a forum to assess the findings of the SNSF project and work being done elsewhere in the world. The papers presented at the conference were published (18) and in December of 1980 the final report of the SNSF Project was also made available (16). Although a broadly coordinated study is not currently being carried out, many of the investigators involved in the original SNSF Project continue to work on the acidic deposition subject through individual projects.

E. Sweden

In 1977 a new research program was established under the auspices of the Research Council of the Swedish National Environment Protection Board. The new program of research was comprised of eleven subprograms. One of the subprograms, entitled, "Effects of Energy Production and Consumption," contains the project "Effects of Acid Deposition on Forests and Waters." Two other agencies, the Fisheries board and the Swedish Council for Planning and Coordination of Research, are also involved in the acidic deposition project. Funding for the total project for the first five years has been, in Swedish currency ($1 U.S. dollar = 7.3 SEK Sweden):

1977/1978	1.10 million SEK
1978/1979	2.10 million SEK
1979/1980	4.07 million SEK
1980/1981	3.35 million SEK
1981/1982	3.45 million SEK

The major problems which have been outlined in motivating these research activities are stated below.

(1) How large a proportion of the total deposition of acidified elements is made up primarily of sulfur and nitrogenous compounds?

(2) Is forest production influenced by acidic deposition?

(3) Which types of soil are the most sensitive and how are they influenced by acidic deposition?

(4) How is surface and groundwater influenced by acidification, and what is the reaction of liming of water and surrounding soils?

Currently a new five-year effort in the Effects of Acidification program have been developed with planning activities scheduled for 1982 and the various fields of work intended for completion in 1986 or 1987, depending on the specific study. The five-year effort will be funded at 4.4 million SEK/yr in total with an addtional 0.5 and 0.9 million SEK/yr in the area of dry deposition and forest production, respectively. The new effort has been organized around the subject areas: (a) deposition, (b) sulfur and nitrogen turnover, (c) acidification of soil and groundwater, (d) indirect effects on vegetation and forest production, (e) ecology of acidified and limed lakes, (f) synthesis, and (g) priority-rating and costs.

All of these areas contain aspects which are geared toward assessing the impacts on forest ecosystems. The subject area on forest production is directed toward answering two key questions:

(1) Is forest production affected by acidification?

(2) What is the role played by land use in the acidification of soils and waters?

The members of the project group "Effect of Acid Deposition on Forests and Waters" are: (a) Professor Folke Andersson (Project Leader), Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, (b) Professor Tryggve Troedsson, Department of Forest Soils, Swedish University of Agricultural Sciences, (c) Doctor Tomas Levander, Swedish National Environment Protection Board, and (d) Doctor Jan Nilsson, Swedish National Environment Protection Board.

F. Federal Republic of Germany

A wide range of research has been initiated in West Germany to address the question of acidic deposition cause and effect. At the national level, the Federal Ministry of the Interior annually develops a Research and Development Program (UFOPLAN) which encompasses investigations to be carried out regarding acidic deposition and terrestrial ecosystems. Work outlined in this program is performed by universities, research institutes, and industrial research laboratories.

The German federal cabinet has developed an investigative program with funding available on October 1, 1982 to study acidic deposition impact on forests. This cooperative effort between various scientific institutions is funded at the level of 12,000,000 DM (approximately $5.1 million U.S.).

One of the major organizations supporting key acidic deposition research related to forests is the Deutsch Forschungsgemeinschaft (German Research Society). Investigations funded by this source, with total funding allocations in German Marks (DM), include:

(1) Actions of Acid Deposits on the Bound Condition of Manganese and Aluminum in Forest Soils (110,000 DM)

(2) Effect of Different Stand-Types on Seepage-Water Quality in a Forest Ecosystem of Schoenbuch (300,000 DM),8

(3) Reaction of Fine-Roots of Spruce to Increasing Aluminum-Concentration in Soil Soilution (level of effort unavailable),

(4) Soil Acidification Due to Emissions in the Crystalline Black Forest (50,475 DM) and

(5) Relations Between the Intensity of Fir Disease and the State of Nutrition of the Affected Stands (level of effort unavailable).

A great many organizations have become directly involved in carrying out Germany's research on forest effects in recent years. Some of these groups are (a) Landesanstalt für Ökologie Landschaftsentwicklung und Forstplanung, (b) Forstliche Versuch - und Forschungsanstalt, Baden-Württemberg, (c) Institut fur Bodenkunde und Waldernährungslehre der Albert-Ludwigs Universität, Freiburg, (d) Institut für Bodenkunde and Standortslehre der Bayerischen Forstlichen Versuchsund Forschungsantalt, and (e) Lehrstuhl für Forstbontanik der Universität München.

Perhaps the best known German investigative program among the North American scientific community involved in forest effects of acid rain research are the studies at the Institut für Bodenkunde und Waldernährung der Georg-August-Universität, Göttingen. This work is being led by Dr. Bernard Ulrich and his colleagues and deals with a variety of studies to determine the cause of the widespread tree growth declines they have reported for the central Europen area. Their studies include investigations on the processes of soil acidification and its impacts on forests, soil aluminum chemical phenomena, fine root production in trees, and other related studies. The program includes laboratory and field investigations with long-term information collected by this group for the Solling and Göttingen forest areas study site near the university. The work of these scientists has played a key role in the recognition of the apparent cumulative impact of pollution stress on German forests, which has been the cornerstone for recent governmental considerations for restricting emissions in West Germany.

G. United Kingdom

As in all countries, much of the research in the United Kingdom on aquatic effects or agriculture has tremendous importance for understanding the relationship between acidic deposition and forest growth. Keeping this in mind, Table 3 lists some of the organizations involved with forestry-related acidic deposition research in the United Kingdom and the project titles. More detailed information on these programs was not available and they are therefore presented here in tabular form. This information was extracted from a more extensive summary of United Kingdom research on acid rain kindly provided by Dr. G. D. Howells of the Central Electricity Research Laboratories at Surrey.

H. Other Countries

There are few, if any, industrialized nations which do not have an interest in the state of knowledge regarding the causes and consequences of acidic deposition. Many countries have embarked on research programs which are naturally motivated by

TABLE 3

ACIDIC DEPOSITION RESEARCH IN THE UNITED KINGDOM RELATED TO FOREST EFFECTS

Organization	Investigators	Project
Central Electricity Research Laboratories (CEGB)	J.E. Rippon/K.A. Brown/ J. Wood/D.J. Foster/ R.A. Skeffington	Soil/Water interactions and leachate to streams; influence of tree cover, tree growth; influence of reducing bogs.
	A.S. Kallend/A.H. Webb	Relationship of rain/stream chemistry, modelling aquatic chemistry of acid waters.
Forest Commission, Northern Experimental Station, Edinburgh (Forestry Commission)	R. McIntosh	Effects of afforestation on surface waters.
	D.G. Pyatt	Run off before/after clear-felling/Kerslope.
Freshwater Fisheries Laboratory, Pitlochry (DAFS)	R. Harriman	Chemistry of acid waters and precipitation in Scotland, particularly in western and south-western Scotland. Influence of afforestation.
	B. Morrison	Fish and invertebrate fauna of acid waters in Scotland. Salmonid populations in acid lakes and streams. Methods of reducing adverse effects of afforestation on salmonid populations.
Hill Farming Research Organization (DAFS)	M.J.S. Floate	Relationship between soil processes and inputs/outputs of acid water.
Institute of Hydrology(NERC)	V. Truesdale/M.D.Newson/ E.M. Morris/G. Roberts/ A. Thomas	Hydrology of forested and grassland catchments; effects of acid rain on chemical weathering: hydrological modelling of soil/ water interaction and snow melt.
	J. R. Blackie	Effects of forests and pasture/ Balquidder catchment/Coalburn/ Great House/Plynlimon.
	D. Peachey	Geochemical cycling.

TABLE 3

ACIDIC DEPOSITION RESEARCH IN THE UNITED KINGDOM RELATED TO FOREST EFFECTS
(Continued)

Organization	Investigators	Project
Institute of Terrestrial Ecology, Banchory and Edinburgh (NERC)	I.A. Nicholson/ J.W. Kinnaird/ D. Fowler/J.N. Cape/ I. S. Patterson	Study of rain chemistry and its geographical variation and effects of forest canopies on soils and soil water.
Macaulay Institute (DAFS)	H. Miller	Acid production/consumption in canopies of various forests, including at Glen Tanar (CEGB) the further changes in soil drainage water beneath different species.
	B.W. Bache	Soil chemical processes involved in acidification.
Nature Conservancy Council, S.W. Scotland Regional Offices, Dalbeattie (NCC)	G.L.A. Fry	Ecology of upland streams in Galloway: effects of afforestation and acid precipitation.
	P. Walsh	Hydrological effects of pre-planting drainage and subsequent growth of trees, Coalburn.
Solway River Purification Board	C.P. James/J.S. Coy	Chemistry and fisheries in acid streams and lakes in Galloway; effects of remedial measures, including deforestation, liming in Loch Dee catchment.
University of Aberdeen	D. A. McLeod	Factors affecting composition of precipitation, river water; weathering.
University of Ediburgh	D. H. Mills	Effects of forest management and and forestry procedures on freshwater fisheries.
	D.C. Ledger	Effect of drainage and afforestation on peat hyrology.
University of Nottingham	S. Hibberd	A theoretical approach to rainwater percolation through a chemically active soil.
Plymouth Polytechnic	L. Terman/A. Williams	Fluvial processes, hydrological pathways and granite weathering on Dartmoor.

the most apparent information needs under individual circumstances. All of the acidic deposition research has some relevance to defining the unknowns regarding forest effects, and many of the countries are specifically concerned with, and have research devoted to, the effects of acidic deposition on forests and soils.

Some of the foreign research efforts on forests and soils include work done in Finland. Most of these investigative programs are at the Universities in Helsinki, Kuopio, Oulu, and Turku. Denmark is carrying out research which includes the work at the Air Pollution Laboratory at Roskilde, the Institute of Plant Ecology in Copenhagen, and the Royal Veterinary and Agricultural University. Research in The Netherlands on acidic deposition and ecological effects is centered at the Research Institute for Nature Management and the University of Wageningen. Switzerland is also involved in this area of research with some of this work being managed by the Swiss Federal Institute for Forestry Research, and in Belgium studies are centered at the University of Antwerpen. Austria is also looking into this area of study with particular interest since evidence in that country, unlike in Scandinavia and North America, indicates no evidence for acidification of surface groundwaters but apparent acidic deposition damage to woodlands.

Poland is conducting acidic deposition studies on biological effects. These studies are conducted by the Botanical Garden of the Polish Academy of Sciences and by the Institute of Silviculture in Cracow. Biogeochemical aspects of acidic deposition are being addressed by the Geological Survey in Czechoslovakia, and in Australia the Australian Forestry Council has taken an active interest in this issue.

Other countries involved in acidic deposition studies include Hungary, Japan, France, Portugal, Spain and Ireland. This brief overview undoubtedly being incomplete with respect to countries and organizations involved in acidic deposition studies which are concerned with forest effects. What is clear, however, is the widespread and substantial interest in this subject which has developed in recent years. Cooperation, coordination, integration and interpretation are the investigative activities which challenge all in light of the extensive and diverse research which is evident.

XII INFORMATION NEEDS OF THE FOREST PRODUCTS INDUSTRY

The level of investigative activity in a particular area of science reflects both (a) the degree of inadequacy in our current ability to explain specific phenomena, and (b) the urgency of a solution for these information needs. The issue of acidic deposition, particularly its effects, is a relatively new area of scientific research facing a tremendous list of unknowns. Coupled with the regulatory implications of any new scientific evidence, this environmental subject has become the focal point of a great deal of research by various organizations to attain needed information.

The impact of acidic deposition on forest productivity is an area of obvious concern for the forest products industry. Numerous studies have already been completed on this topic and many more have been initiated. It is also possible to draw on experience from our basic scientific understanding of soils, soil chemistry, ecology, forest influences, and related fields to explain and predict forest ecosystem behavior. Individuals concerned with this issue from all sectors of society must bear in mind that broad conclusions with regard to acidic deposition impacts on forests are not possible. Specific effects on forest productivity which might be detected would be a function of a given quantity and quality of deposition along with specific species, soil, climatic, and topographic parameters.

It is possible, however, to outline broad areas of information needs with regard to the effects of acidic deposition on forests. Several recent publications have addressed this area of needs assessment (15,18,127,151,177). The following list represents the current information needs of particular concern for the forest products industry with respect to acidic deposition effects on forest productivity.

(1) Evaluation of Forest Soil Sensitivity to Acidic Deposition - One of the most important information needs facing acidic deposition impact assessment efforts with regard to forest productivity is the ability to identify those soils with the greatest sensitivity. This requires both (a) the identification of critical parameters for measurement, and (b) the appropriate sampling and analysis methodologies to achieve these goals. Soil sensitivity designations with regard to forest productivity may be significantly different from sensitivity with respect to other ecological processes. It is important to understand the chemical interactions which result from acidic deposition inputs to forest soils, and the rates at which these interactions proceed, in order to define the mechanisms for forest effects. Assessing soil sensitivity to potential acidic deposition-induced forest productivity alterations will provide the identification of those forested areas where (a) the early detection of acidic deposition impacts is most probable, (b) implications of acidic deposition impacts for forest management decisions are most relevant, and (c) the long-term monitoring of critical soil properties will be most fruitful in assessing the effects of acidic deposition on forest ecosystems.

(2) Determination of the Quantity and Quality of Atmospheric Contributions to the Forest Ecosystem - As information becomes available on the mechanisms by which acidic deposition may alter ecosystem functioning it will be of primary importance to know the level of atmospheric contribution to specific forested areas to assess potential impacts. This information requires the continual monitoring of atmospheric deposition over time, using high quality procedures for sampling, handling and analysis with adequate quality assurance.

The long-term monitoring of deposition inputs to forests is vital to understanding potential interactions with forested ecosystems. Specific data for acidic atmospheric contributions of gases, particulates, fog drip, dew, rain, sleet, snow, and rime must be developed in order to adequately evaluate the phenomena which are operative under field conditions. Of particular concern are the important commercial timber growing areas not yet covered by the National Atmospheric Deposition Network (NADP). To date, the forest products industry is responsible for supporting the establishment and maintenance of nine NADP stations in Wisconsin, Idaho, Arkansas, Washington, Oregon, Texas and Georgia. Better coverage for commercial timberlands is still urgently needed, particularly in the southeastern United States.

(3) Development of Improved Dry Deposition Measuremeent Techniques - Presently available technology to measure the dry deposition (i.e. gaseous and particulate inputs) for forested ecosystems is inadequate due to the forest canopies' tremendous ability to filter these materials. This component of atmospheric deposition is particularly important for forest vegetation where the large surface area and complex physical and chemical matrix of forest canopies provides for a large contribution of gases and particulates to total atmospheric input. Estimates indicate the contribution of S and N in some forests from dry deposition can equal or exceed wet deposition inputs (176). The relationship between the quantity and quality of dry deposition to forest canopies and subsequent alterations in precipitation as it passes through the canopy needs to be addressed.

(4) Investigation of Critical Forest Ecosystem Phenomena which have been Identified as Playing a Major Role in Acidic Deposition Impact Assessment - Research to date which has addressed the interaction between acidic deposition and forest ecosystems has revealed some specific subjects of particular relevance in explaining potential changes in forest productivity. Although research on a wide range of aspects for this issue will ultimately be needed to best understand acidic deposition impacts, focusing investigative efforts on the most important issues will provide the earliest and most efficient answers to critical

information needs. Some of these areas of concern are the effects of acidic deposition on (a) the mobilization and form of soil Al, (b) the rate of nitrification, (c) the rate of organic matter decomposition, (d) cationic nutrient leaching, (e) forest canopy interactions and throughfall/stemflow chemistry, (f) fertilizer effects for tree growth, (g) microbial populations, (h) S, N and H biogeochemistry, (i) mineral weathering rates, and (j) natural versus acidic deposition-induced soil acidification processes.

(5) Identification and Development of Key Forest Management Alternatives Influenced by Acidic Deposition Effects - One of the benefits previously mentioned for identifying forest soils sensitive to acidic deposition-induced forest productivity changes is the location of those commercial timberland areas where management decisions would most likely benefit by considering potential acidic deposition alterations to the site. If acidic deposition alters tree growth and element cycling there could be subsequent impacts on fiber quality and yield, water quality and yield, wildlife populations, or recreational uses. Information is needed to define the impacts acidic deposition may have on forest management decisions regarding (a) site preparation, (b) species selection, (c) genetic improvement, (d) intermediate cuttings, (e) forest fertilization, (f) harvesting, (g) prescribed burning, (h) pesticide applications, and (i) drainage. At present only a few theoretical treatments of this subject are available, and research is needed to define the options which should be considered in forest management prescriptions.

(6) Evaluation of Dendrochronology as an Investigative Approach to Defining the Relationship Between Acidic Deposition and Forest Growth Trends - Due to the ubiquitous nature of acidic deposition and a lack of historical records on deposition chemistry, natural scientists have recently turned to dendrochronological and dendroecological studies to evaluate difficult time-dependent relationships. These studies utilize tree growth rings to provide historical information on the past environment and on tree growth trends over long periods of time. Some of the recent research has indicated changes in tree growth patterns may be associated with acidic deposition through the use of indirect correlations. Further work is needed to (a) define the validity of dendroecological techniques in evaluating acidic deposition impacts, (b) develop the technology and statistics for using these methods in the best possible fashion, and (c) provide a larger data base on which conclusions may be drawn.

(7) Establishment of Long-Term Investigations on Forested Ecosystems to Assess Acidic Deposition Impacts - There seems to be general agreement in the scientific community that the effects of acidic deposition on forest productivity, if demonstrated,

will be manifest through the development of chronic alterations in the ecosystem. This logically leads to the need for long-term investigations which monitor ecosystem dynamics and deposition inputs over time. This type of research is the best means by which to attain sound information on (a) mineral weathering rates, (b) nutrient fluxes, (c) heavy metal accumulations, (d) plant pathogen interactions, and (e) organic carbon cycles. The acidic deposition effects on future forests also depends on its impacts with regard to tree reproduction, seed germination and stand regeneration which can best be evaluated over time through long-term investigations.

(8) Development of the Analytical Tools Which can be Used to Assess the Economic Consequences of Acidic Deposition on Forest Productivity - Results from research which becomes available on the role of acidic deposition in forest ecosystems will be quickly translated into factors that guide social and political questions. In the long run, analytical tools must be developed which will provide a means of interpreting scientific findings into meaningful information to guide regulatory decisions. Some of the questions which arise are; can the acidic deposition impacts on forest productivity issues be meaningfully addressed in a cost/benefit approach, what is the dose/response relationship between acidic deposition components and forests, what is the individual impact of other atmospheric pollutants (e.g. O_3) and what are the interactive and synergistic effects of these pollutants with acidic deposition, what is the price for alternative management presciptions which might be needed to ameliorate acidic deposition effects, can soil-site evaluation equations be used to predict forest product yield changes? These types of questions must be answered before meaningful evaluations of acidic deposition effects can be accomplished.

The abaove should not be interpreted as an exhaustive list of information needs on the acidic deposition and forest effects subject. Results of currently active and planned research will no doubt provide refinements in these perceived needs along with new questions to be answered. The items discussed are intended to represent the most important information needs with regard to the impacts of acidic deposition on forest productivity which currently face the forest products industry in light of the present state of knowledge on this subject.

XIII SUMMARY AND CONCLUSIONS

A summary and the main conclusions with regard to acidic deposition and forest productivity which may be drawn as a result of recent research on acidic deposition and present state of knowledge on this subject.

outstanding information needs, is included in the following text. These are arranged in four major subject areas, namely (a) acidic deposition and its extent in the United States, (b) acidic deposition and its relation to forest productivity, (c) acidic deposition and its relation to forest soils, and (d) forest products industry information needs regarding the effects of acidic deposition on forest productivity.

A. Acidic Deposition and its Extent in the United States

(1) Scientific awareness of acidic atmospheric materials due to anthropogenic activities is not new and was apparently the topic of writings and research over 300 years ago.

(2) Acidic wet deposition, that is precipitation less than pH 5.6, is impacting on the eastern United States and Canada, with isolated areas also affected in the western United States. Acid precipitation also falls in many European countries, the United Kingdom, and Mexico.

(3) Dry deposition (i.e. gases and particulates) contributes a significant portion of the acidic atmospheric inputs to terrestrial ecosystems and may equal or exceed wet deposition inputs in some locations. Little or no information is available on the effects of interactions between wet deposition and the gaseous components of air pollution on tree growh.

B. Acidic Deposition and its Relation to Forest Productivity

(1) Forests are ecosystems which naturally have an acidifying effect on soils and acidic deposition impacts must be evaluated as an increment to existing processes.

(2) As yet, evidence of damaging effects from acidic deposition on forest productivity has not been conclusively documented under field conditions, nor has research provided evidence which shows acidic deposition is not a significant stress factor in forests.

(3) Forest vegetation significantly alters the quantity, quality, and distribution of precipitation as it moves through tree canopies.

(4) Softwood canopies tend to acidify, whereas hardwood canopies tend to neutralize the acidity in precipitation. Alterations in precipitation chemistry are due to (a) the washing and leaching of surface deposited materials, (b) absorbed materials, and (c) excreted metabolites.

(5) Direct impacts on tree vegetation such as tissue injury or disrupted physiological processes have been shown in artificial

experimental situations with aqueous treatment concentrations of acidity significantly greater than mean ambient conditions. Tissue damage has been demonstrated only with artificial rain pH values of approximately 3.0 or less.

(6) Impacts of acidic deposition on future forests may be manifest by alterations in (a) pollen production, (b) pollination, (c) fertilization, (d) fruit and seed set, (e) seed germination, (f) seedling development, (g) juvenile development, and (h) flower and cone initiation.

(7) The input of nutrients, particularly N, from atmospheric deposition has the potential for significantly increasing forest productivity due to this element often being deficient in forests.

(8) The most probable mechanisms for the indirect impact of acidic deposition on forest vegetation to cause alterations in forest productivity, should they occur, would be to (a) accelerate the leaching loss of nutrients from foliage, (b) have an impact on symbiotic organisms in forest canopies, (c) alter tree susceptibility to other environmental stresses, and (d) change the ability of tree roots to function normally.

(9) Dendrochronological studies show some evidence of declining growth in several pine species, red spruce, and chestnut oak since the early 1950's. Statistical evaluations considering possible environmental factors suggest acidic deposition may be associated with these growth trends.

(10) Research in the Solling forests of West Germany indicate forest damage is occurring and may be linked with an air pollution-induced destabilization of the forest ecosystem.

(11) Theoretical considerations on the effects of acidic deposition for forests suggest forest management decisions regarding (a) site preparation, (b) forest fertilization, (c) species selection, (d) breeding, (e) intermediate cuttings, (f) pesticide use, (g) timber harvesting, and (h) overall shifts in land use, may benefit by consideration of acidic deposition-related phenomena.

C. Acidic Deposition and its Relation to Forest Soils

(1) Indirect impacts of acidic deposition on forest productivity would likely occur through alterations in forest soils. The most important factors which may affect tree growth appear to be (a) added nutrients, (e.g. N and S), (b) accelerated leaching of base cationic nutrients (e.g. Ca, Mg, K), (c) changes in organic decomposition and nitrification processes, and (d) mobilization of toxic elements (e.g. Al).

(2) The acidic deposition phenomenon has been associated with greater levels of heavy metals (e.g. Pb, Zn, Cu, V, Cr, Ni) in soils and soil solutions due to (a) greater atmospheric inputs of these substances, and (b) acid-induced alterations in the mobility of these metals.

(3) Atmospheric contributions of N are largely retained in the forest ecosystem through biological utilization. The availability of N is intimately associated with the rate of organic matter decomposition, and the form of N utilized (i.e. NH_4^+ or NO_3^-) plays a critical role in soil acidification processes.

(4) Atmospheric contributions of S to forest soils (a) may be adsorbed by soil sesquioxides, (b) may leach from the soil with an associated cation, (c) could be taken up by tree roots and incorporated into vegetative tissues, (d) may form a solid soil phase with Al, (e) has an important role in determining soil cation exchange capacity, and (f) can become part of a total soil S pool dominated by organic S forms.

(5) Evidence has shown that acidic deposition may increase the level of mobile Al in soils with detrimental impacts on terrestrial and aquatic ecosystems. In regard to forest species, elevated soil solution Al can damage tree roots and alter their physiological functioning.

(6) The mobility and toxicity of Al in soil solutions is a strong function of soil solution pH and the level of organic materials in solution. The level of Ca and the Ca/Al ratio in soil solutions also plays an important part in Al toxicity to biological processes. The source of Al from podzolic forest soils appears to be dominated by Al from humus and B2 horizons.

(7) "Acidic deposition", "soil acidification", and "cation leaching" are not synonymous terms. The first term refers to modern atmospheric inputs of acidic character in specific geographic regions while the last two are natural soil processes which can occur independently of one another.

(8) Soil sensitivity to acidic deposition must be clearly defined with regard to the impacts considered (e.g. forest productivity, soil acidification, cation leaching, aquatic effects) in order to (a) determine the critical parameters to measure, and (b) correctly interpret the soil's sensitivity.

(9) The various schemes currently available to assess soil sensitivity to acidic deposition primarily utilize the following parameters: (a) soil pH, (b) cation exchange capacity, (c) base saturation, (d) soil texture, (e) soil depth, and (f) soil

organic matter content. The ability to adsorb SO_4^{2-} is also seen as a critical parameter.

D. Information Needs Regarding the Effects of Acidic Deposition on Forest Productivity

(1) The primary information needs with regard to acidic deposition and forest productivity, have been identified as the: (a) evaluation of forest soil sensitivity to acidic deposition, (b) determination of the quantity and quality of atmospheric contributions to the forest ecosystem through more extensive sampling of acidic deposition in commercial forest areas, (c) development of improved dry deposition measurement techniques for forested ecosystems, (d) investigation of critical forest ecosystem phenomena which have been identified as playing a major role in acidic deposition impact assessment, (e) identification and development of key forest management alternatives influenced by acidic deposition considerations, (f) evaluation of dendochronology as an investigative approach to defining the relationship between acidic deposition and forest growth trends, (g) establishment of long-term investigations on forested ecosystems to assess acidic deposition impacts, and (h) development of analytical tools which can be used to assess the economic consequences of acidic deposition on forest productivity.

(2) The research programs described in the text which are currently in place and planned will provide valuable information necessary to address many of the information needs pertaining to acidic deposition and forests. These programs do not focus specifically on the forest products industry's timberland resources, which leaves specific needs regarding these resources to be met by individual company initiatives. The specific information needs include (a) the integration of specific soil measurements into existing company forest management programs in order to (i) identify the sensitivity of the forest soils to acidic deposition and possible alterations in productivity, (ii) establish the data base on soil chemistry to allow an assessment of trends which may be apparent over time, and (iii) identify those sites which may require special management considerations in light of potential acidic deposition-induced alterations, (b) an improvement of the data base to provide information on the ambient air quality and level of dry deposition in company timberlands where almost no information exists, yet will be vital, in order to ultimately assess and predict the effect of acidic deposition on forests, and (c) an effort to evaluate the health status of company timberlands in order to quantify the possible occurrence of forest damage for which no apparent causes can be identified. Should such damage be evident and discernable, careful monitoring of the symptoms, extent, distribution, and location of these areas is needed in order to determine the cause and development of the problem.

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ncasi special report

NATIONAL COUNCIL OF THE PAPER INDUSTRY FOR AIR AND STREAM IMPROVEMENT, INC., 260 MADISON AVENUE, NEW YORK, N.Y. 10016

REPORT ON THE DEVELOPMENT OF FLUE GAS DESULFURIZATION SYSTEM CAPITAL COSTS FOR VARIOUS-SIZED UNITS

SPECIAL REPORT NO. 83-06
JULY 1983

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July 15, 1983

SPECIAL REPORT 83-06

REPORT ON THE DEVELOPMENT OF FLUE GAS DESULFURIZATION SYSTEM CAPITAL COSTS FOR VARIOUS-SIZED UNITS

In the review of background information generated by EPA for use in developing New Source Performance Standards for industrial boilers, the National Council staff detected what appeared to be a discrepancy between capital construction costs for industrial sized boiler flue gas desulfurization systems in an EPA contractor report and those appearing in other published information on the costs for similar systems on utility sized boilers.

To determine if the staff analysis was a proper one, Burns and McDonnell, a consulting firm with extensive flue gas desulfurization system design and capital cost experience for both industrial and utility sized boilers, was contracted to assemble flue gas desulfurization system costs for an array of boiler sizes.

The attached special report was prepared directly from the Burns and McDonnell report with supplemental elaboration by NCASI staff. Dr.John Pinkerton, our Air Quality Program Manager, who managed this project, which was co-funded by NCASI, the American Paper Institute and the National Forest Products Association, also provided the staff elaboration on the original report.

The capital costs developed in this report for various flue gas desulfurization systems are based on actual installed costs wherever possible and on detailed engineering estimates otherwise. These capital costs have been compared to flue gas desulfurization capital cost estimates prepared by an EPA contractor. For similar flue gas desulfurization systems with equivalent SO_2 removal capabilities, it was found that the EPA estimates are 40 to 75% lower than the capital costs developed in this report for industrial sized boilers with heat inputs from 100 to 400×10^6 Btu/hr.

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This report did not develop information on operation and maintenance costs. However, NCASI staff review of operating and maintenance costs reported in EPA documents for flue gas desulfurization systems on industrial and utility boilers reveals that those for utility boilers are about one half those for industrial boilers. While it is not possible to identify the more realistic of the two estimates, it is suggested that total flue gas desulfurization costs shown in the EPA report, which was the subject of this study, should be subject to careful review.

Your comments and inquiries are invited on matters covered in this report and should be directed to Dr. John E. Pinkerton or myself at the telephone or address above.

Yours very truly,

Russell O. Blosser
Technical Director

ROB:gs
Attach.

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REPORT ON THE DEVELOPMENT OF FLUE GAS DESULFURIZATION SYSTEM CAPITAL COSTS FOR VARIOUS-SIZED UNITS

I FOREWORD

The Environmental Protection Agency has during the past two or more years been assembling background information for use in the development of New Source Performance Standards for SO_2 emission control for industrial boilers. In the review of the cost data in this background information, the National Council staff observed what appeared to be a major discrepancy between construction cost estimates for flue gas desulfurization systems for industrial boilers in a contractor report prepared for EPA for use in development of NSPS, and published information on the capital costs for flue gas desulfurization systems in the larger utility boilers. In summary, the unit construction costs for industrial boiler flue gas desulfurization systems were consistently less on a common unit costing basis, than for utility boilers. Such a situation runs counter to well known engineering cost principles in that the economy of scale factor was absent.

To determine if the staff analysis was a proper one, Burns & McDonnell, a consulting firm with extensive flue gas desulfurization system design and capital cost experience for both industrial and utility sized boilers were contracted to assemble flue gas desulfurization system costs for an array of boiler sizes.

The following NCASI special report was prepared directly from the Burns & McDonnell report. The foreword and Part F in Section V were prepared by the NCASI staff. In those cases where explanatory editing was carried out within the report by the NCASI staff, this editing is underlined for identification. The capital costs developed in this report for various flue gas desulfurization (FGD) systems are based on actual installed costs wherever possible and on detailed engineering estimates otherwise. These capital costs have been compared to flue gas desulfurization capital cost estimates prepared by an EPA contractor. For similar FGD systems with equivalent SO_2 removal capabilities, it was found that the EPA estimates are 40 to 75% lower than the capital costs developed in this report for boilers with heat inputs from 100 to 400 x 10^6 Btu/hr. Although apparently the EPA estimates did not include (a) redundant equipment to insure that adequate SO_2 removal would be accomplished at all times, and (b) interest charges during construction, these two factors alone cannot account for all of the differences between the two sets of cost figures. Detailed examination of additional reasons for these significant differences was beyond the scope of this study.

The cost of flue gas desulfurization consists of two major components, (a) the capital cost associated with the engineering design, equipment purchase, and installation of the FGD system, and (b) the expenses associated with the operation and maintenance of the FGD system. This report focuses solely on the installed capital cost component because it can be quantified in a reasonable straightforward manner compared to operating and maintenance costs. Calculation of installed capital costs does not require assumptions regarding (a) levels of maintenance, (b) frequency of equipment replacement, (c) chemical usage and price, (d) operating manpower, (e) waste disposal, (f) power costs for system operation, (g) stack gas reheat cost, or (h) capacity utilization, all of which are needed to arrive at an estimate of annual operating and maintenance costs.

The EPA contractor's report does include estimates of annual operating and maintenance expenses for FGD systems on industrial sized boilers ranging from 30 to 400 x 10^6 Btu/hr. Given the observed significant differences in capital costs between the EPA report and this report, it is logical to inquire if the EPA operating and maintenance cost estimates are reasonable. A cursory comparison of a dual alkali FGD system (90% removal efficiency on a 3.5% sulfur coal) operating and maintenance cost for the electric utility industry cited in another EPA contractor document (EPA-450/2-78-007a, Electric Utility Steam Generating Units - Background Information for Proposed SO_2 Emission Standards) with those for a similar industrial boiler flue gas desulfurization dual alkali system estimated in the EPA/Radian document indicates that the industrial boiler FGD operating and maintenance cost estimate is only one-half of that for an equivalent sized utility system ($0.50/$10^6$ Btu, mid-1978 dollars for a 250 x 10^6 Btu/hr boiler running at 60% capacity). Because of the many assumptions necessary to obtain an operating and maintenance cost estimate, it is not possible to identify the more realistic of the two estimates. This example comparison merely indicates that the operating and maintenance costs given in the EPA document for industrial boilers are open to question, and that any estimates for total flue gas desulfurization costs based on the EPA document should be subject to careful review.

II INTRODUCTION

A. Purpose of the Report

The purpose of this report is to (a) present flue gas desulfurization (FGD) system cost curves for three FGD processes over a range of boiler sizes from 100 to 10,000 MBtu/hr, (in this report, 1 MBtu = 10^6 Btu), and (b) compare these costs with similar costs presented in a recent EPA report (EPA-450/3-82-021, August 1982). The comparison of the costs presented in the two reports includes a discussion of the cost differences and the possible reasons for the observed differences.

The cost curves presented in this report represent adjusted cost data obtained from actual FGD installations and are based on specific design criteria developed especially for this study. The design criteria and the methodology utilized in developing these FGD system cost curves are summarized for the purpose of providing an accurate picture of the actual costs of FGD systems. The FGD system cost curves also show the economy-of-scale relationship between FGD costs and boiler size.

B. Organization of the Report

The report includes a Summary and Conclusions Section which follows the main body of the report. The body of the report is organized into three parts as outlined below.

Section III describes the three types of FGD systems, limestone, dual alkali and spray dryers, examined in this report. The descriptions are intended to give the reader an overview of the types of FGD processes including special characteristics and equipment requirements for each type of FGD system.

Section IV defines the FGD design criteria necessary to develop consistent cost data over the wide range of boiler sizes examined in this report. General design criteria which apply to all three FGD processes include site conditions, fuel analysis, boiler specification, SO_2 removal efficiency and general equipment requirements. The specific design criteria for each individual FGD process includes the basic equipment requirements and design criteria for that equipment.

Section V describes the methodology used in developing FGD system costs and presents the FGD cost curves. This section includes descriptions of (a) the sources for the actual FGD cost data, (b) the methods by which FGD cost data were checked for completeness and adjusted where necessary, and (c) how the data were escalated or de-escalated to mid-1978 dollar values. The Methodology Section also describes the cost adjustments that were made to actual FGD cost data to account for various fuel sulfur contents and sulfur dioxide removal efficiencies.

The FGD system capital cost curves and a discussion of the economy-of-scale relationships for industrial and utility boiler applications are presented at the end of this section. The FGD capital cost curves summarize costs in terms of mid-1978 dollars per MBtu/hr versus boiler size (MBtu/hr).

III FLUE GAS DESULFURIZATION SYSTEM DESCRIPTIONS

A. Background and General Descriptions

Three flue gas desulfurization (FGD) systems are examined in this report, they are limestone and dual alkali (both wet FGD systems), and lime spray dryers. Each of these FGD processes works on the principle of absorption, whereby the SO_2 in the combustion gas is transferred from the gas phase into an alkali solution or slurry.

In wet limestone FGD systems, the absorbent is water containing a suspended, only slightly soluble alkali. Therefore, the wet limestone process is classified as a slurry system. Alkali slurries are not easy to handle because they are abrasive and the suspended solids tend to settle out. The products of the absorption process also have limited solubility and may precipitate forming scale on the equipment. On the other hand, since the products are relatively insoluble, waste disposal is a matter of physical separation of the solids and the water.

The dual alkali FGD system is a clear liquor process which uses a highly soluble alkali absorbent and forms soluble salts as reaction products. The clear liquor is easy to handle and does not settle out of solutions which greatly simplifies the type of absorption equipment. However, since the products of the absorption process are soluble salts, the waste disposal process includes an extra step to produce an insoluble waste product that can be physically separated.

The dry FGD system also utilizes water in preparing an alkali solution or slurry. However, the amount of water injected into the absorber is carefully controlled so that the gas does not become saturated, allowing moisture condensation. The dry waste product can be handled more easily by a less complicated waste disposal system.

B. Wet Limestone Flue Gas Desulfurization System Description

In the limestone FGD process, a limestone slurry is sprayed, usually countercurrent to the gas flow to provide contact between the slurry and the SO_2 in the gas. Once the SO_2 is absorbed in the liquor, a number of chemical reactions take place, resulting in the formation of calcium sulfite and sulfate. Because this process is nonregenerable, a portion of the spent slurry is constantly purged from the process and additional limestone is added.

Since the limestone system is a one-step throwaway process, the process chemistry is much simpler than the dual alkali system described later. The low solubility of calcium carbonate in water, however, requires that the absorbing liquor be a slurry of suspended limestone particles. This slurry is not easy to handle because it is abrasive and solids will settle out forming deposits unless constantly kept moving. The control of the process chemistry is also critical because the reaction products are also only slightly soluble and also tend to settle.

Because the limestone system is a slurry process, the absorption equipment is both large and complex. The absorption equipment consists of spray tower with a high liquid flow rate or various designs of internal packing, plates, or venturi arrangements to maximize the gas-liquid interfacial area. The open spray tower design is most common because of lower cost and lack of surfaces which might plug or scale. Special attention is required at the wet/dry interface and mist eliminators are needed to avoid scaling and plugging. Slurry pH and density must be fully regulated to optimize both SO_2 removal efficiency and limestone utilizaton, but also to prevent scaling and plugging.

Makeup slurry for the system is usually prepared by wet grinding pebble-sized limestone rock. The wet grinding equipment consists of a wet ball mill and a classifier arrangement to produce a slurry as fine as 85 percent through 325 mesh (approximate).

A throwaway waste product is produced by the limestone system. The dewatering process typically includes a thickener (hydroclones have also been used) to concentrate the solids followed by a vacuum filter or centrifuge to dewater the solids. The FGD waste product is then mixed with boiler fly ash as collected by a precipitator or baghouse, to provide a stabilized sludge that can be transported via truck or conveyor to a disposal area.

C. Dual Alkali Flue Gas Desulfurization System Description

The dual alkali process uses highly soluble sodium (NH_4, Mg or Al can also be used) absorption solution followed by the addition of lime or limestone to precipitate the sulfite and bisulfite reaction waste products and regenerate the absorption solution. The absorption phase of the process utilizes an aqueous alkaline solution to absorb the SO_2 forming soluble sulfite and bisulfite ions. A slipstream of the recirculating absorbent solution is treated with lime or limestone to form a calcium base precipitate from the soluble sodium sulfite and bisulfite waste products. The regenerated solution is then returned to the absorption loop.

Dewatering of the reacted slurry is required to separate the calcium base precipitate from the absorbent liquor and recover the soluble alkali liquor. The main components of the dewatering system are the thickener and rotary vacuum filters. Slurry from the reactor tank where lime or limestone slurry is mixed with liquor, is fed to the thickener. Clarified liquor overflows to the thickener hold tank prior to return to the system for pH control. The thickener underflow slurry is pumped to the filter system where solids separation is completed. The filter cake is washed with fresh water to recover the soluble alkali absorbent. The filter cake may then be transported directly to a disposal area.

D. Dry Lime Flue Gas Desulfurization System Description (Spray Dryer)

In the spray dryer system, an alkali reactant, in the form of solution or slurry, is pumped to the atomizers of the spray dryer absorber module. The atomizers are used to create a dispersed spray of fine droplets which are intimately mixed with the incoming flue gas. The SO_2 contained in the flue gas is absorbed on the surface of the droplets and the alkali material reacts with the gas to form sulfites and sulfates. The droplets simultaneously undergo drying and a portion of the spent solids is collected in the base of the drying chamber. The remainder of the solids is collected together with fly ash still entrained in the flue gas by a fabric filter or electrostatic precipitator.

The operation of the spray dryer absorber system is controlled by four process mechanisms. The first is the atomization of the absorbent which is related to the required surface area of the spray droplets necessary for proper drying. Intimate contact between the spray droplets and flue gas is also necessary for high SO_2 absorption rates. Similarly, proper gas dispersion is required for mixing and also for the prevention of moist or wet lumps in the drying chamber. Finally, the gas residence time, and thus the chamber size, must be sufficient to permit maximum SO_2 absorption.

Spray dryer systems utilize solids recycle to improve system stoichiometry (mole reactant per mole of SO_2 at the absorber inlet). The process of solids recycle involves mixing a portion of the waste solids with the alkali slurry. Recycling improves reactant utilization and takes advantage of any alkalinity in the fly ash. Dry waste products of calcium sulfites/sulfates and fly ash can be conveyed or pneumatically transferred to a temporary storage silo to await transportation to a disposal site.

IV COST DEVELOPMENT DESIGN CRITERIA

A. Purpose

Flue gas desulfurization (FGD) system capital costs are affected by factors such as fuel analysis, sulfur removal efficiency, gas volume, equipment included and in-service date. In order to provide FGD costs for various boiler sizes, the above factors are held constant by developing design criteria for boilers, fuel, operating conditions and FGD systems. The design criteria are applied to actual FGD system costs to provide a consistent set of FGD system cost curves. This section includes descriptions of the general design criteria applied to all FGD systems and specific design criteria applied to each type of FGD system. The specific design criteria includes a detailed summary of the equipment and design assumptions incorporated into each of the three FGD systems examined in this study.

B. General Design Criteria

The general design criteria listed apply to all three FGD systems. All FGD system costs are for new boiler installations, because of the difficulty of estimating site specific retrofit requirements. Equipment costs for support systems such as electrical power, instrument air and make-up water are proportioned according to requirements by the FGD system.

The predominant design criteria influencing FGD system price is the design gas volume and sulfur dioxide mass flow rate. The design gas volume is affected primarily by coal analysis, amount of combustion air, gas temperature and site elevation. Plant site elevation for this study is 500 feet above sea level. Unlike site elevation, the other factors affecting gas volume and sulfur dioxide concentration cannot be held constant but will vary within a known range of values. Good engineering practice dictates that the design gas volume reflect this range of variation, therefore, the design gas volumes for each case are increased by 10 percent.

The fuel selected for this study is bituminous coal. An ultimate analysis for a bituminous coal was developed and used in all combustion calculations. In order to perform combustion calculations, the ultimate analysis for each sulfur content must add up to 100 percent. Ash was chosen as the constituent to vary since it has no effect on the volume of combustion gas produced. A normal bituminous ash analysis would be expected to vary within a range large enough to compensate for the 1.0 to 3.5 percent sulfur range indicated. The ultimate analyses (typical of Missouri, Ohio, Illinois, and Kansas bituminous) are shown in Table 1.

TABLE 1

ULTIMATE ANALYSIS FOR A BITUMINOUS COAL
(percent by weight)

	Low Sulfur	Medium Sulfur	High Sulfur
Carbon	70.0%	70.0%	70.0%
Hydrogen	4.0%	4.0%	4.0%
Nitrogen	1.0%	1.0%	1.0%
Sulfur	1.0%	2.0%	3.5%
Water	7.0%	7.0%	7.0%
Ash	9.0%	8.0%	6.5%
Oxygen	8.0%	8.0%	8.0%
Higher Heating Value	12,000 Btu/lb	12,000 Btu/lb	12,000 Btu/lb

Boiler-related parameters affecting gas volume are combustion air requirements, leakage and gas temperature. Boilers with a thermal input rate greater than 250 MBtu/hr are pulverized coal boilers. Spreader stoker boilers are used below 250 MBtu/hr. The larger pulverized coal boilers require 125 percent total air for combustion and an air heater. Air heater leakage is assumed to be 15 percent. The spreader stoker boilers require 130 percent total air and are not equipped with an air heater because the economizer can serve that function. For all boilers, the gas outlet temperature (absorber inlet design gas temperature) is 350 degrees F.

Structural design and freeze protection are also affected by site-related parameters. Structural design is based on an assumed plant site located in a Seismic Zone 1 thereby eliminating the need for specially designed (e.g. earthquake) foundations and structures. Freeze protection is accomplished by providing metal wall panel enclosures. Enclosures offer the advantages of protected maintenance and work areas at a long-term cost equal to or less than the costs of heat tracing and insulation.

All FGD systems include ductwork, complete with turning vanes, internal stiffeners and insulation and lagging, to direct combustion gases to and from the absorber modules. Included in the limestone and dual alkali FGD costs is the ductwork from the particulate control device outlet (excluding transitional ductwork required to reduce cross-sectional area or connecting two or more particulate control devices) to the absorber inlet. Also included are bypass ductwork and ductwork from the absorber outlet to the stack. The spray dryer FGD cost includes a similar amount of ductwork except it starts at the air heater outlet and ends at the particulate control device inlet. Structural-steel required to support the ductwork is included in its cost, however, the ductwork is assumed not to be designed to support equipment or structures connected to it such as the stack and air heater.

Capital costs for particulate control devices, such as electrostatic precipitator, baghouse and venturi scrubber, are not included in the FGD system costs. Particulate removal is required for installation regardless of whether or not a FGD system is provided. Because particulate control costs are not included, all three FGD system costs presented in this report can be compared on an equal basis.

C. Flue Gas Desulfurization System Design Criteria

(1) General - Each of the FGD systems described is considered a closed-loop system producing a throwaway waste that can be handled safely and transported to a waste disposal area. All FGD systems include a spare absorber module and a metal wall panel building enclosure. The limestone and dual-alkali FGD systems include ductwork to bypass 100 percent of the gas volume at 70 fps. The spray dryer FGD system includes bypass ductwork for reheat only. Complete bypass capability can be accomplished by directing gas through a nonoperating absorber module.

A spare absorber module is included with each type of FGD system to allow steady-state, full-load operation of the boiler without violation of sulfur dioxide emission standards if one absorber becomes inoperative. The spare module permits maintenance of the inoperative absorber module with the boiler at full load. Although this type of redundancy is not necessarily "standard engineering practice," it is similar to the design philosophy for equipment which is required for full-load operation and which has a potential for frequent removal from service for repairs.

(2) Wet Limestone FGD - The equipment for the wet limestone process is divided into the twelve systems described below.

(a) Absorption System - This system removes sulfur dioxide from the flue gas by contacting it with a slurry of limestone, calcium sulfite and calcium sulfate. The Absorption System consists of the following equipment: (i) absorbers, (ii) slurry recycle tanks, (iii) recycle tank mixers, (iv) absorber recycle pumps, (v) mist eliminator wash water tanks, (vi) wash water pumps, (vii) dampers, (viii) valves and piping, and (ix) instruments and controls.

The absorbers are countercurrent spray towers designed for a saturated gas velocity of 8 ft/sec and a residence time of 5 sec. Design SO_2 removal efficiency is 90 percent with a liquid to gas (L/G) ratio of 60 gpm/1000 cfm for low sulfur (1 percent) fuel, 70 gpm/1000 cfm for medium sulfur (2 percent) fuel, and 90 gpm/1000 cfm for high sulfur (3.5 percent) fuel. Towers are constructed of carbon steel with rubber lining, except for the wet/dry interface area and outlet ductwork which are a high nickel-chromium alloy. Mist eliminators are pressure-molded, fiberglass-reinforced plastic (FRP), two-stage chevrons.

Sulfur dioxide removal efficiencies of 70 and 50 percent will be accomplished with combustion gas bypass. Utilizing gas bypass to achieve reductions in overall removal efficiency, reduces the size and cost of the entire FGD system by the percentage of gas bypassed.

The bypass ductwork, however, is not reduced in size since it must still bypass 100 percent of the combustion gas volume produced by the boiler.

Slurry recycle tanks are covered, carbon steel tanks with organic, corrosive-resistant linings. A separate tank, sized for a slurry hold time of 10 minutes, is required for each absorber tower.

Absorber recycle pumps are rubber-lined centrifugal pumps; two 100 percent capacity pumps are provided when the design slurry flow rate can be handled by one pump and three 50 percent capacity pumps when two pumps are required to handle the design flow rate. When three or more pumps are required to provide the design slurry flow, spare capacity pumps are not provided. Instead, the total capacity of the pumps is increased to greater than 100 percent of the design slurry flow. Slurry piping is rubber-lined carbon steel.

(b) Limestone Handling System - This system transports limestone from the rail car or truck unloading point to the ready pile and from the ready pile to storage silos where it is stored until dispensed for production of limestone slurry. The Limestone Handling System includes the following equipment: (i) limestone unloading hopper, (ii) limestone unloading hopper gate valves, (iii) limestone unloading hopper vibrating feeders, (iv) belt conveyors and/or bucket elevators, (v) conveyor galleries, (vi) belt scales, (vii) belt conveyor magnetic separators, (viii) limestone lowering well, (ix) limestone ready pile reclaim hopper, (x) limestone ready pile dischargers, (xi) limestone ready pile vibrating feeders, (xii) limestone storage silo, (xiii) limestone silo bin dischargers, (xiv) limestone storage silo flop gate, (xv) limestone storage silo dust collectors, (xvi) ventilation system, and (xvii) instruments and controls.

Limestone can be stored on site in an uncovered pile for long-term storage; therefore, the limestone storage silo provides three days' storage. The smaller capacity systems utilize a bucket elevator to transfer limestone from long-term storage to the limestone storage silo.

(c) Limestone Preparation System - This system wet grinds the limestone and delivers the slurry obtained to the Absorption System. The Limestone Slurry System includes the following: (i) limestone weigh feeders, (ii) ball mills, (iii) mill product tanks, (iv) classifiers, (v) mill product pumps, (vi) limestone slury storage tanks, (vii) limestone slurry transfer pumps, (viii) piping and valves, and (ix) instruments and controls.

It is assumed that this system includes two 100 percent capacity ball mills complete with classifiers to produce a 30 percent suspended solids limestone slurry product with 85 percent of the solids less than 325 mesh. The slurry storage tank provides a two-day limestone slurry storage capacity.

(d) Oxidation Air System - This system provides low-pressure (18-psig) compressed air to the oxidation tanks to oxidize the suspended solids in the waste slurry from calcium sulfite ($CaSO_3$) to calcium sulfate ($CaSO_4$ gypsum). The sulfate crystals settle faster and dewater easier than the sulfite crystals. Also, the sulfate compound produced is a more easily handled waste product. The Oxidation Air

System consists of the following: (i) intake filter silencers, (ii) forced oxidation air compressors (centrifugal), (iii) blowoff silencers, (iv) instruments and controls, and (v) piping and valves.

(e) Waste Slurry System - This system transfers the overflow from the absorber reactor tanks through the forced oxidation tanks to the thickener. The system also includes the emergency hold tank and a drainage sump. The Waste Slurry System includes the following: (i) waste slurry tank, (ii) waste slurry tank agitator, (iii) waste slurry transfer pumps, (iv) waste slurry sump, (v) waste slurry sump agitator, (vi) waste slurry sump pumps, (vii) oxidizer feed tank, (viii) oxidation tanks, (ix) thickener feed tank, (x) emergency hold tank, (xi) emergency hold tank pumps, (xii) piping and valves, and (xiii) instruments and controls.

(f) Sludge Dewatering System - This system concentrates and dewaters the suspended solids present in the absorber waste slurry for further processing and final disposal by the Sludge Handling System. Concentration, or thickening, takes place in a round mechanical lift thickener with dewatering occuring in a single-stage vacuum filter. Various building drainage sumps are also included in the Disposal System. The Sludge Dewatering System includes the following: (i) thickener, (ii) thickener underflow pumps, (iii) fabric vacuum filters, (iv) belt conveyors, (v) thickener tunnel, pug mill and sludge dewatering building sump pumps, (vi) pug mill and sludge dewatering building sump mixers, and (vii) instruments and controls.

It is assumed that this system includes one 100 percent capacity thickener to produce a 30 percent solids underflow. A spare thickener is not required because of the storage capacity available in the emergency hold tanks. Fabric vacuum filters (including one spare) produce a 50 percent solids sludge cake from the thickener underflow.

(g) Sludge Handling System - This system transforms the sulfur dioxide (SO_2) scrubber sludge and fly ash into a product suitable for final disposal. The Sludge Handling System consists of the following equipment: (i) belt conveyors and scales, (ii) fly ash silo knife gates and rotary feeders, (iii) pug mills, (iv) pug mill dust collectors, and (v) instruments and controls.

It is assumed that this system produces a stable waste material for transportation off site.

(h) Gas Cleaning and Sludge Dewatering Control System - The Control System automatically controls the gas cleaning equipment and associated fluids as required to maintain flue gas emissions within the gas cleaning system specifications, and disposes of waste products generated by these systems. The Gas Cleaning and Sludge Dewatering Control System is contained in an air-conditioned and heated control room in the FGD enclosure and consists of the following components: (i) gas cleaning control board, (ii) Sludge Handling System control board, (iii) analog controls, (iv) logic controls, (v) control switches, lights, operating stations, recorders and indicators, (vi) analyzers, transmitters, controllers, control drives, valves and alarms, and (vii) events recorder with printer.

(j) Reclaimed Water System - This system recycles clarified process water and provides liquid storage capacity within the closed-loop absorber and scrubber sludge dewatering handling system. The Reclaimed Water System includes the following: (i) reclaim water tank, (ii) reclaim water pumps, (iii) valves and piping, and (iv) instruments and controls.

(3) Auxiliary Systems - The following systems are required for proper operation of the FGD system.

(a) Makeup Water System - This system provides good quality water for various process and equipment uses in the absorber and sludge dewatering systems which cannot utilize reclaim water. The source of makeup water is the plant service water or cooling water systems. The makeup water system provides water for the following systems and uses: (i) mist eliminator wash, (ii) absorber inlet and outlet isolation damper flush, (iii) solids disposal system, (iv) reclaim water system, (v) pump seal water, (vi) cooling water to various pieces of equipment, (vii) fly ash wetting in the dustless unloader, and (viii) scrubber sludge and fly ash wetting in the pug mills.

(b) System Seal Water - This system provides seal water to pumps in the FGD system. The Seal Water System consists of the following equipment: (i) seal water tank, (ii) seal water pumps, (iii) seal water strainer, and (iv) valves and piping.

(c) System Instrument Air - This system distributes clean, dry air from the plant compressed air system to operate control valves, solenoid valves and other instruments in the absorber, reagent preparation and waste handling areas. This system includes: (i) compressed air receiver tank, (ii) air filters, and (iii) piping and valves.

(4) Dual-Alkali FGD - The equipment for the Dual-Alkali FGD System is separated into the ten systems described below.

(a) Absorption System - This system removes sulfur dioxide from the combustion gas by contacting it with a highly soluble soda ash solution. The Absorption System consists of the following equipment: (i) absorbers, (ii) absorbent solution recycle tanks, (iii) recycle tank mixers, (iv) absorber recycle pumps, (v) mist eliminator wash water tanks, (vi) wash water pumps, (vii) dampers, (viii) valves and piping, (ix) instruments and controls, (x) soda ash silo, (xi) soda ash bin dischargers, and (xii) rotary feeder.

The absorbers will be tray type constructed of lined carbon steel or stainless steel. The absorbers are designed for a liquid to gas (L/G) ratio of 10 gallons per thousand acf saturated at 130 degrees F and a gas velocity of 8 fps through the absorber. The Dual-Alkali System will achieve 90 percent removal with a 10 percent soda ash solution. Removal efficiencies of 70 and 50 percent will be accomplished with combustion gas bypass.

The Dual-Alkali Absorption System will be provided with a soda ash storage silo sized for a 5-day emergency feed rate. The emergency feed rate will occur when the sludge solids wash system is nonoperative. During emergency conditions, approximately 10 percent of the sodium ion is leaving the system in the sludge cake while under normal conditions, (i.e. with solids washings) only about 2 percent of the soluble sodium ion leaves the system. Under normal conditions, the soda ash silo provides 30 days storage.

(b) Quicklime Handling System - This system unloads pebble quicklime from rail cars and/or trucks, and pressure conveys the product to storage silos. The Quicklime Handling System includes the following: (i) unloading hopper, (ii) unloading filter/receiver, (iii) rotary feeders, (iv) unloader vacuum pumps, (v) unloader pressure blower, (vi) transfer blowers, (vii) quicklime silos, (viii) bin dischargers, (ix) pneumatic conveyor piping, (x) blower filters and silencers, (xi) bin vent filter fans and filters, and (xii) diverter valves, control valves, instruments and controls.

The quicklime handling system silo will provide 30-day on-site storage.

(c) Regeneration System - This system precipitates the soluble sodium sulfite and bisulfite waste products from the absorption system recirculating loop. The Regeneration System includes the following equipment: (i) quicklime silo, (ii) lime silo bin vibrator, (iii) lime weigh feeder, (iv) lime slaker, (v) silo vent filter fans and filter, (vi) reactor tank, (vii) reactor tank agitator, (viii) emergency hold tank and pumps, (ix) thickener feed pumps, and (x) instruments and controls.

The following assumptions apply:

The Regeneration System will utilize pebble quicklime providing 90 percent lime utilization in the regeneration process at a 10-minute retention time in the reaction tank. The lime preparation system will include two 100 percent capacity slakers and a feed system. The lime preparation feed silo will provide a minimum of 10 days storage. For the smaller units burning low sulfur coals, bulk storage will not be required because the lime preparation feed bin can be sized to hold the 30-day lime requirement.

(d) Sludge Dewatering System - This system concentrates and dewaters the suspended solids present in the Regeneration System slurry for further processing and final disposal by the Sludge Handling System. Concentration or thickening takes place in a round mechanical lift thickener with dewatering occurring in a single-stage vacuum filter. Various building drainage sumps are also included in the Disposal system. The Sludge Dewatering System includes the following: (i) thickener, (ii) thickener underflow pumps, (iii) fabric vacuum filters with wash system, (iv) belt conveyors, (v) thickener tunnel, pug mill and sludge dewatering building sump pumps, (vi) pug mill and sludge dewatering building sump mixers, (vii) instruments and controls, and (viii) absorbent solution return pumps.

The Sludge Dewatering system will be equipped with a 100 percent capacity thickener producing 30 percent suspended solids. A spare thickener is not required because of the storage available in the emergency hold tanks. Fabric vacuum filters (including one spare) produce a 50 percent solids cake for transportation off site. The fabric vacuum filters are equipped with a filter cake wash system to recover soluble alkali absorbent.

(e) Sludge Handling System - This system serves the same purpose and includes the same equipment as described for the Wet Limestone FGD system.

(f) Gas Cleaning and Sludge Dewatering Control System - This system serves the same purpose and includes the same equipment as described for the Wet Limestone FGD system.

(g) Auxiliary Systems - The following systems each serve the same purpose and include the same equipment as described for the Wet Limestone FGD system which includes: (i) makeup water system, (ii) seal water system, and (iii) system instrument air.

(5) Dry Lime FGD (Spray Dryer) - Equipment for the dry lime FGD is separated into the systems described below.

(a) Absorption System - This system removes sulfur dioxide from the combustion gas by contacting it with a dispersed spray of fine lime slurry droplets. The absorption system includes the following equipment: (i) absorbers, (ii) reheat ductwork, (iii) slurry feed tank, (iv) slurry feed pumps, (v) slurry atomizers, (vi) dampers, (vii) valves and piping, and (viii) instruments and controls.

The spray dryer system will utilize a liquid to gas ratio of 0.3-gallon per 1,000 scf, have a design gas velocity through the absorber of 3 fps and a 12-second gas residence time. The towers and ductwork are constructed of carbon steel. Reheat via gas bypass ductwork is required to keep the treated gas above its dew point, thereby eliminating the possibility of moisture condensation which would adversely affect the performance of the downstream particulate removal device.

Stoichiometry for the process is based upon a 20 degree F approach temperature to saturation and varies with the SO_2 inlet concentration, percent removal and solids recycled as shown on Table 2. The stoichiometry requirements presented in Table 2 are not intended to be representative of a manufacturer's guaranteed lime stoichiometry. Rather, they represent design values appropriate for use in sizing reagent preparation and related equipment. A minimum stoichiometry requirement of 0.7 mole of lime per mole of SO_2 at the absorber inlet is applied to all cases. Slurry recycle is not employed unless required to achieve the required percent SO_2 removal (high sulfur and 90 percent removal).

TABLE 2

DESIGN STOICHIOMETRY REQUIREMENTS FOR SPRAY DRYER

% S Fuel	SO_2 ppm (Wet)	% SO_2 Removal	Stoichiometry Required
1%	700 ppm	50	0.7
		70	0.9
		90	2.0
2%	1400 ppm	50	0.7
		70	1.0
		90	2.2
3.5%	2600 ppm	50	0.8
		70	1.3
		90	2.0 (R)

(R) - 50 percent recycle of sorbent with lime, assumes no alkalinity fly ash.

(b) Quicklime Handling System - This system unloads pebble quicklime from rail cars and/or trucks, and pressure conveys the product to storage silos. The Quicklime Handling System includes the following: (i) unloading hopper, (ii) unloading filter/receiver, (iii) rotary feeders, (iv) unloader vacuum pumps, (v) unloader pressure blower, (vi) transfer blowers, (vii) quicklime long-term storage silos, (viii) bin dischargers, (ix) pneumatic conveyor piping, (x) blower filters and silencers, (xi) bin vent filter fans and filters, and (xii) diverter valves, control valves, instruments and controls.

The Quicklime Handling System will provide 30 days' on-site storage.

(c) Lime Preparation System - The Lime Preparation System provides lime slurry for use in the absorption system. The system includes the following equipment: (i) quicklime silo, (ii) lime silo bin vibrator, (iii) lime weigh feeders, (iv) lime slakers, (v) mill product tanks, (vi) classifiers, (vii) mill product pumps, (viii) lime slurry hold tanks, (ix) lime slurry transfer pumps, (x) piping and valves, and (xi) instruments and controls.

The Lime Preparation System includes a minimum 10-day-capacity lime silo. Packaged lime preparation systems can be utilized for storage capacities less than 5,000 ft^3. As was the case for the dual-alkali FGD system, some small units are capable of 30 days storage in the lime preparation feed bin. Two lime slakers (one 100 percent backup) with a 3:4 water to lime ratio produce a 10 percent suspended solids slurry. The lime slurry hold tank is sized for 30-minute retention to allow for lime stabilization.

(d) Slurry Recycle System - When required, this system recycles approximately 50 percent of the waste product to increase lime utilization. The system includes the following equipment: (i) waste product storage tank, (ii) screw conveyor, (iii) slurry recycle tank, (iv) slurry recycle tank mixers, and (v) slurry recycle pump.

(e) Gas Cleaning and Waste Handling Control System - The Gas Cleaning and Waste Handling Control System automatically controls the gas cleaning equipment and associated fluids as required to maintain flue gas emissions within the cleaning system specifications, and disposes of waste products generated by these systems. This System consists of the following components: (i) gas cleaning control board, (ii) waste handling system control board, (iii) analog controls, (iv) logic controls, (v) control switches, lights, operating stations, recorders and indicators, (vi) analyzers, transmitters, controllers, control drives, valves and alarms, and (vii) events recorder with printer.

(f) Waste Handling System - This system transports dry absorber waste from the absorber hopper to a storage silo to await transportation to a disposal area. This system utilizes much of the same equipment required by the ash handling system. The cost of this system reflects the cost of equipment and additional equipment capacity required specifically for the FGD system. Equipment costs include: (i) absorber hopper intake valves, (ii) pneumatic conveyor piping, (iii) diverter valves, and (iv) instruments and controls.

Additional equipment capacity costs include: (i) transfer blower capacity and (ii) storage silo capacity.

(g) Auxiliary System - These systems each serve the same purpose and include the same equipment as described for the

Wet Limestone FGD system which include: (i) makeup water system, (ii) seal water system, and (iii) system instrument air.

V DEVELOPMENT OF FLUE GAS DESULFURIZATION SYSTEM CAPITAL COSTS

A. Introduction

Flue Gas Desulfurization (FGD) System capital costs were developed for limestone, dual-alkali and spray-drying FGD processes for installation on coal-fired boilers ranging in size from 100 to 10,000 MBtu/hr. For each type of FGD process, two sets of costs were developed: (a) costs for coal sulfur contents of 1.0, 2.0 and 3.5 percent, and (b) sulfur dioxide removal efficiencies of 50, 70 and 90 percent.

The FGD System costs for each set were based on actual installed costs, where available, and on estimated costs developed especially for this study. Both actual and estimated costs were developed to reflect the design criteria outlined in Section IV. Actual cost data were adjusted upward or downward to arrive at costs for the nominal sulfur and removal efficiency percentages identified.

The following sections describe the methodology used in the development of actual costs, cost estimates and cost adjustments.

B. Collection and Development of Actual Cost Data

(1) Actual Cost Data - The FGD system cost curves presented in this report are based primarily on actual cost data for industrial and electric utility applications. The extensive use of actual FGD costs required the ability to (a) identify and separate costs into FGD systems or components and, (b) establish an index year for the costs. These prerequisites were established so that actual costs could be adjusted for the design criteria defined in Section IV and corrected to mid-1978 dollar values. Actual FGD system cost data were obtained from both Burns & McDonnell FGD projects and other sources. Burns & McDonnell FGD projects include eleven limestone FGD systems ranging in size from 750 to 6700 MBtu/hr and two spray dryer systems at 175 and 6700 MBtu/hr. Additional sources of FGD cost data included data from the EPA Utility Flue Gas Desulfurization Information System Data Base and information published by owners and manufacturers concerning actual installed FGD system costs. These sources provided costs for a 200 MBtu/hr spray dryer and dual alkali systems at 200, 1200 (2 systems), and 4,000 MBtu/hr.

(2) Cost Identification - As indicated earlier, the usefulness of actual FGD system costs depends on the availability of a detailed system description and cost breakdown. A detailed system description includes, for example, information concerning the amount of sulfur in the fuel, percent sulfur dioxide removal, gas volume treated, size of the boiler served, percent gas bypass, and in-service date. A detailed cost breakdown includes information concerning not only the costs of equipment and installation but also equipment size, equipment redundancy, and special materials of construction.

The detailed system cost breakdown prepared for this report to use in checking actual cost data for completeness includes the breakdown of direct construction costs and indirect costs.

Direct construction costs include the cost of material and installation for: (i) FGD absorbers, (ii) ductwork and dampers, (iii) reagent preparation equipment, (iv) FGD enclosure and structures, (v) foundation and substructures (vi) sludge dewatering equipment, (vii) process piping and pumps, (viii) power wiring and electrical equipment, (ix) instruments and controls, (x) site preparation, and (xi) painting, paving, cleanup and miscellaneous.

Indirect costs include the costs of: (i) engineering costs, and (ii) interest during construction.

Taxes were not included as an indirect cost of the FGD systems since pollution control equipment is generally tax exempt.

(3) Cost Indexing - Following the identification and breakdown of actual FGD costs into direct construction and indirect costs, all cost data were either escalated or de-escalated according to the date for which the costs were reported. The cost adjustment factors used to correct costs to mid-1978 values appear in Table 3. The cost adjustment factors are derived from the weighted average of several indices. The indices include those commonly used in Burns & McDonnell FGD absorber and related contracts for labor and material escalation, the Handy Whittman Indicies for Utility Boiler-Erected Structural Steel and Labor Crafts, and applicable indices for electrical and control wiring and equipment, pumps and piping. The cost adjustment factors were submitted to several FGD suppliers and found to be representative of the actual cost escalation experienced by these suppliers.

TABLE 3

COST ADJUSTMENT FACTORS

Year	CA Factor	Year	CA Factor
Mid-1973	0.57	Mid-1978	1.00
Mid-1974	0.73	Mid-1979	1.09
Mid-1975	0.81	Mid-1980	1.19
Mid-1976	0.85	Mid-1981	1.29
Mid-1977	0.91	Mid-1982	1.37

C. Development and Application of Cost Estimates

Cost estimates were developed primarily to provide continuous cost curves for the FGD systems as defined in Section IV of this report, for boilers ranging from 100 to 10,000 MBtu/hour. Cost estimates were provided for equipment or FGD systems that were excluded according to the detailed system cost breakdowns for actual FGD costs. Cost estimates were also developed for entire FGD systems when no actual FGD cost data was available. All estimated cost data are based on Burns & McDonnell FGD projects, cost data for similar-sized equipment and equipment manufacturer's data or were prepared by Burns & McDonnell's Estimating Department given the design criteria in Section IV for FGD applications. Again, all cost estimates were corrected to mid-1978 dollars before being added to FGD system costs.

D. Flue Gas Desulfurization Capital Cost Adjustments

The final stage in the development of FGD capital costs involved adjustments to provide costs for 1.0, 2.0, and 3.5 percent sulfur and 50, 70, and 90 percent sulfur dioxide removal efficiency at a known boiler size. Adjustments were made for gas volume, percent sulfur and percent SO_2 removal.

(1) Adjustment for Gas Volume - Each of the actual FGD systems examined for this report have absorber modules which were sized to a certain design gas volume as determined on a plant by plant basis. Before using the actual FGD cost data, it is necessary to convert the actual design gas volume into an equivalent boiler size based on the assumed parameters for site elevation, fuel analysis, combustion air, leakage and gas temperature as defined in Section IV. The adjustment for gas volume is accomplished by dividing each FGD design gas volume by a constant correction factor, with the units of actual cubic feet per MBtu.

The reason for this adjustment is that the actual cost data was based on design parameters which do not coincide with the design assumptions of the study.

The adjustment results in an equivalent boiler size in MBtu per hour at which 100 percent of the design gas volume is treated. For FGD systems with two or more absorber modules, but without a spare absorber module at the design gas volume, one of the modules is designated as a spare and the design gas volume reduced accordingly. This adjustment results in an equivalent boiler size that includes a spare FGD module. The cost of this FGD system is then corrected to reflect reduced reagent and sludge handling requirements.

(2) Adjustment for Percent Sulfur - Sulfur content directly affects waste solids production and reagent requirements. Cost adjustments for sulfur contents of 1.0, 2.0, and 3.5 percent sulfur reflect equipment changes in reagent handling, reagent preparation, Absorption System's slurry recycle (L/G requirements), Sludge Dewatering System and Sludge Handling System. Variations in sulfur content also have a slight effect on control systems, piping, and electrical wiring by virtue of equipment requirements. However, these cost changes are judged negligible in comparison to the changes in equipment costs and, therefore, have not been included in the adjustments.

(3) Adjustment for Percent Removal Efficiency - As indicated earlier, the adjustment for gas volumes resulted in the cost for a FGD system that treats 100 percent of the combustion gas with one spare module. From this cost data, adjustments are made to provide costs for FGD systems with 70 percent and 50 percent sulfur dioxide removal efficiencies.

For limestone and dual-alkali FGD systems, lower percent removal efficiencies are accomplished with combustion gas bypass. The amount of combustion gas bypass required for a FGD system with a design SO_2 removal efficiency of 90 percent, as defined by the FGD design criteria in Section IV, is shown in Table 4.

TABLE 4

EQUIVALENT SULFUR DIOXIDE REMOVAL EFFICIENCIES FOR A KNOWN AMOUNT OF COMBUSTION GAS BYPASS

Equivalent SO_2 Removal Efficiency	Combustiion Gas Bypass Percentage
90	0
70	22
50	44

The amount of combustion gas bypass indicated in Table 4 gives an indication of the reduction in size of all FGD systems (and costs) except for bypass ductwork and ID fans.

For spray dryer systems, adjustment of the SO_2 removal efficiencies is accomplished by the adjustment of system stoichiometry. Stoichiometry requirements are shown on Table 2. Increasing system stoichiometry increases the cost of all spray dryer systems and equipment except for ductwork, ID fans, and the absorber module. Stoichiometry requirements also indicate the desirability of solids recycle at high sulfur and high removal efficiency. Consequently, spray dryer FGD system costs, at 3.5 percent sulfur and 90 percent removal, include the additional cost of the Slurry Recycle System.

E. Flue Gas Desulfurization Capital System Costs

FGD capital costs are presented in the attached Figures 1, 2, and 3 limestone FGD unit costs, Figures 4, 5, and 6 dual-alkali FGD unit costs, and Figures 7, 8 and 9 spray dryer FGD unit costs. All FGD system capital costs are summarized by cost curves representing mid-1978 dollars per million Btu per hour versus boiler size in million Btu per hour heat input. Presented in this form, the phenomenon known as "economy of scale" is dramatically demonstrated.

In addition to the cost curves, flue gas desulfurization system costs are also summarized in Table 5. Table 5 presents FGD cost percentages broken down for material, installation, engineering and interest during construction at several different boiler sizes. It should be noted that interest during construction is not dependent on unit size but rather is totally dependent on the terms of financing used. Actual cost data provided costs for interest during construction within a range of 20 percent to 30 percent of total FGD costs.

Included in all of the FGD cost percentages summarized in Table 5 is the cost of redundant equipment. Redundant equipment is described in Section IV as equipment for which providing redundancy is not "standard engineering practice," but spare capacity required for continuous full-load operation. This includes the spare absorber module and the spare equipment capacities, as described in Section IV, for the reagent preparation and the sludge dewatering systems. The cost of redundant equipment, as a percentage of total FGD system costs, varies slightly with the size of the system. For example, the cost of redundant equipment for unit sizes of 1,000 MBtu/hr and less vary within the range of 20 percent to 25 percent of the total FGD system costs. For a unit size of 6,000 MBtu/hr the cost of redundant equipment is within the range of 10 percent to 15 percent of the total FGD system cost.

TABLE 5

FGD COMPONENT COSTS AS A PERCENTAGE OF FGD SYSTEM CAPITAL COSTS AT GIVEN BOILER SIZE

Component	Boiler Size (MBtu/hr			
	200	2000	4000	6000
Equipment, Material and Structures	37%	41%	45%	45%
Erection, Installation and Contractor Fees	30%	27%	24%	24%
Engineering and Start-up	8%	7%	6%	6%
Interest During Construction	25%	25%	25%	25%

F. Further Comparison to the EPA Capital Cost Estimates

As discussed earlier, the capital cost estimates contained in the EPA document "Costs of Sulfur Dioxide, Particulate Matter, and Nitrogen Oxide Controls on Fossil Fuel Fired Industrial Boilers" are significantly lower than those shown in Figures 1 through 9. In the EPA report, FGD cost estimates are given for dual alkali and spray dryer systems for model boiler sizes of 30, 75, 150 and 400 MBtu/hr. For the dual alkali FGD systems, removal efficiencies of 50 and 90% were considered for coals with sulfur contents of 3.54 and 0.6%. For the spray dryer, costs were only developed for a 50% removal efficiency for a 0.6% sulfur coal.

It is illustrative to graphically compare the EPA cost estimates to those developed in this report for similar FGD systems and removal efficiencies. These comparisons are shown in Figure 10 (dual alkali systems, 90% SO_2 removal), Figure 11 (dual alkali system, 50% SO_2 removal), and Figure 12 (spray dryer, 50% removal). The EPA cost figures were taken from Tables 3-1 and 3-2 in the Radian report for the dual alkali systems which did not include particulate matter control as part of the SO_2 control costs. Spray dryer costs were estimated from Table 3-2 by subtracting the fabric filter cost (to be consistent with the Burns & McDonnell costs) from the combined SO_2 and particulate matter control cost. All costs were normalized to mid-1978 dollars per 10^6 Btu/hr boiler heat input.

Figures 10 through 12 show the EPA capital cost estimates are lower than those developed by Burns & McDonnell by factors of roughly 2.5 to 4. Although costs for some redundant equipment and interest charges during construction were included in the

Burns & McDonnell cost estimates but apparently not in the EPA values, these two factors are not nearly great enough to account for the large observed differences. While it is beyond the scope of this study to identify why the EPA cost figures are so much lower, it seems likely the Radian cost algorithms do not realistically reflect installed costs of dual alkali and spray dryer FGD systems experiences at a number of actual facilities.

VI SUMMARY AND CONCLUSIONS

A. Summary

(1) This report presents capital costs developed from actual installed cost data for three flue gas desulfurization (FGD) systems, limestone, dual alkali and spray dryer. The costs were developed for the purpose of comparison to similar costs presented in a recent report prepared by the Radian Corporation for the U.S. Environmental Protection Agency titled, Costs of Sulfur Dioxide, Particulate Matter and Nitrogen Oxide Controls on Fossil Fuel-Fired Boilers (EPA-450/3-82-021).

(2) The FGD system costs presented in this report are for bituminous coals with sulfur contents of 1.0, 2.0 and 3.5 percent, and for sulfur dioxide removal efficiencies of 50, 70 and 90 percent over a range of boiler sizes from 100 to 10,000 MBtu/hr. (The cost of redundant equipment is included in the cost estimates. Redundant equipment is defined as spare capacity equipment needed for continuous operation of the FGD system, beyond the equipment judged necessary for "good engineering practice"). To provide consistent cost data over the range of boiler sizes, all costs are corrected to mid-1978 dollars and are based on design criteria developed especially for this study. The design criteria define the process systems and equipment included in the costs for each type of FGD system and allow for adjustment of cost estimates to account for items not included in the costs of actual installed FGD systems.

(3) The costs of particulate control devices for any of the three FGD systems examined are not included in this report. Particulate control devices are required for coal-fired boilers regardless of whether or not a FGD system is provided. Often, as in the case of the Radian report, the cost of a particulate control device is included in the cost of spray dryer FGD systems, because it is considered an integral part of the system. However, particulate removal is equally important for a wet FGD system because of the adverse effect of particulate on absorber performance and maintenance. Because particulate removal is not included, all three FGD system costs are compared on an equal basis.

(4) In general, the cost of particulate control equipment depends on the type of equipment employed and the particulate removal efficiency required. The two most common types of equipment for collecting the relatively small-sized fly ash particles from coal-fired boilers are electrostatic precipitators and baghouses. Both of these types can be designed for the high removal efficiency which is commonly required to meet state and Federal particulate emission standards. Although the cost of a complete particulate control system depends on the size of the boiler, the type of equipment selected and the degree of conservation exercised by the designer, the cost of a complete particulate control system is estimated to range from 30 to 85 percent of (and in addition to) the cost of the FGD system. This estimate is based on achieving an emission rate of 0.05lb/MBtu which is the particulate emission limitation expected to be proposed for new coal-fired industrial boilers. The exact cost of particulate control equipment depends on the various factors involved and must be determined on a case-by-case basis.

(5) FGD system costs are presented in the form of mid-1978 dollars per MBtu/hr versus boiler size in MBtu/hr. In this form, the economy of scale relationships between FGD system cost and boiler size is easily demonstrated. Unit costs (dollars per MBtu/hr) are larger for smaller boilers than larger boilers.

B. Conclusions

(1) The FGD system for a limestone FGD system is slightly greater than for a dual alkali FGD system, while the spray dryer FGD system is the least expensive. The primary reason for the cost differences is the complexity of the design and equipment required for the absorption modules and absorbent pumps and piping. In addition, the spray dryer FGD system requires less waste handling equipment than either the dual alkali or limestone FGD system.

(2) It should be noted that while the FGD system costs presented in this report are representative of actual installed costs, they cannot be asumed to represent the cost of any specific FGD system. Factors affecting FGD system costs such as site specific requirements, competitive bidding, regional economic conditions and local and state air pollution regulations cannot be included in a study of this nature. However, by limiting some of the cost variables identified in this report and by defining general and specific design criteria for the FGD systems, the resulting FGD system costs are as representative as reasonably can be expected.

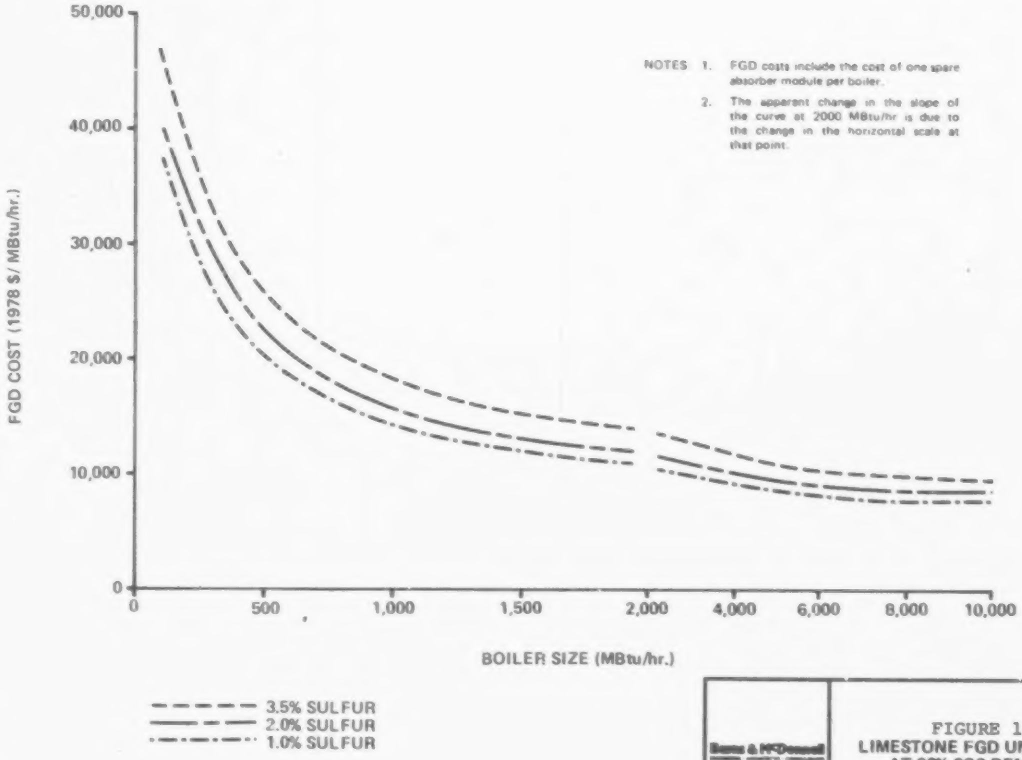
C. Comparison to Radian Report

(1) The Radian report presents costs for dual-alkali and spray dry FGD systems for application on coal-fired boilers. Dual-alkali system costs are for coals at high sulfur (3.54 percent) and low sulfur (0.6 percent) and removal efficiencies of 50 and 90 percent. The spray dryer system costs are for low-sulfur coal at a 50 percent removal efficiency.

(2) Costs for both of these FGD systems were derived from equations (cost algorithms) developed by the Acurex Corporation based on cost information contained in an earlier Radian Corporation report. The Radian report does not state exactly what equipment costs are included in the algorithms although the report indicates that the algorithms provide "...total direct costs without prior computation of equipment and installation costs." (Apparently the Radian estimates do not include the cost of any redundant equipment). Flue gas desulfurization costs based on the algorithms are lower than the costs presented in this report.

(3) The Radian report does include general design criteria for the FGD systems identified. However, the criteria are limited to absorber type, materials of construction, pressure drop and liquid-to-gas ratio. This report attempts to more clearly define each FGD system process and the equipment required.

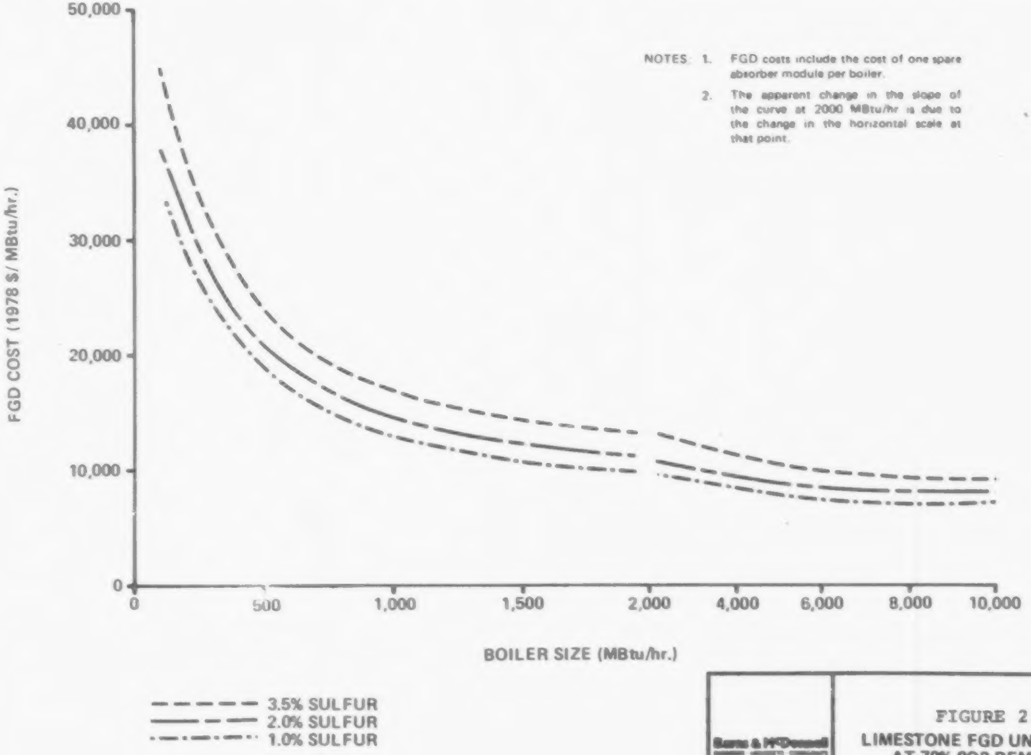
(4) The Radian report contains costs for a shop-assembled "package" and field-erected coal-fired boilers, however, the report does not indicate if any FGD systems are shop assembled. The use of shop-assembled equipment offers a cost advantage over field erection and is used to some extent on all sizes of systems. On a small industrial boiler FGD system, for example, a package lime preparation system (including reagent silo, slakers, slurry tank, pumps and piping) may be purchased shop assembled, while the absorber tower and other equipment may be too large to assemble off site. Even large FGD systems may have shop-assembled units, such as control panels and reagent silos. As a result, the cost savings for small boilers utilizing shop-assembled or package FGD systems or processes is not as dramatic as might be expected and a "break" in FGD system costs for smaller systems is not observed.



NOTES 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

FIGURE 1
LIMESTONE FGD UNIT COSTS
AT 90% SO2 REMOVAL



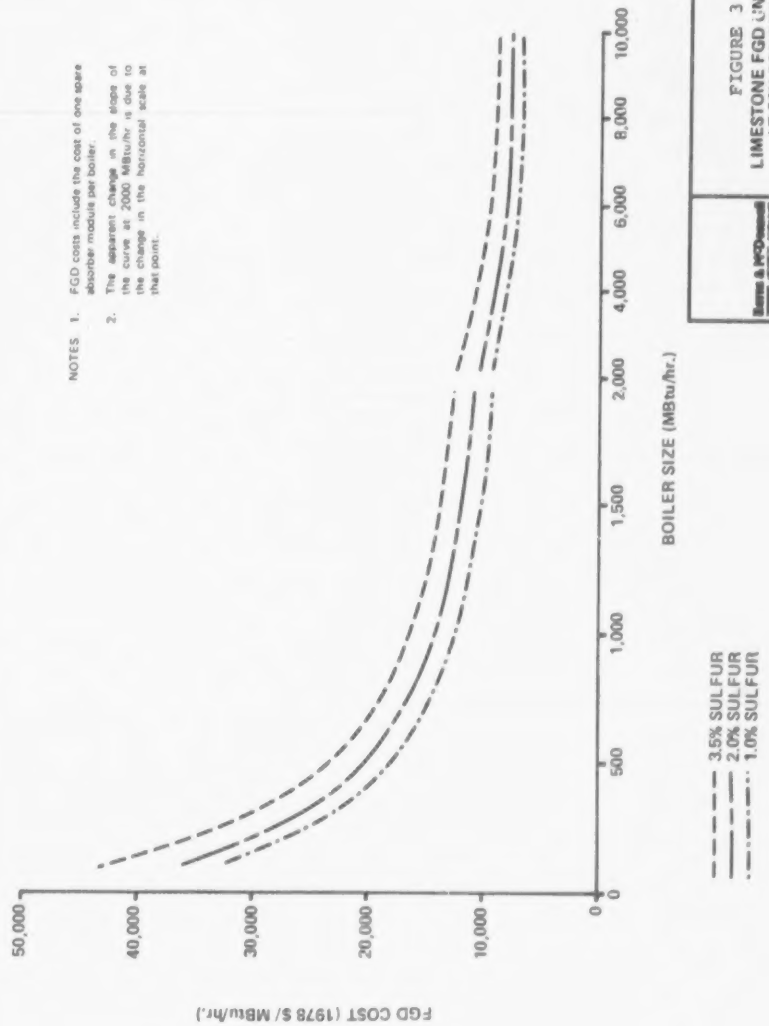
NOTES: 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

Burns & McDonnell

FIGURE 2

LIMESTONE FGD UNIT COSTS AT 70% SO2 REMOVAL

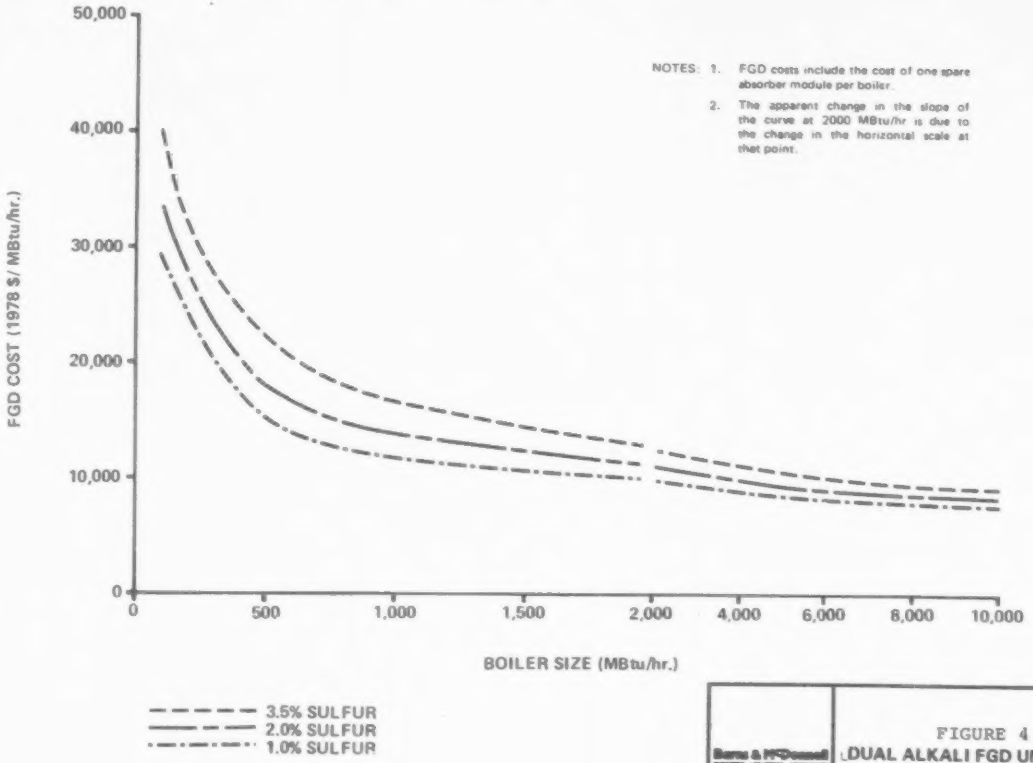


NOTES 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

Burns & McDonnell

FIGURE 3
LIMESTONE FGD UNIT COSTS
AT 50% SO2 REMOVAL

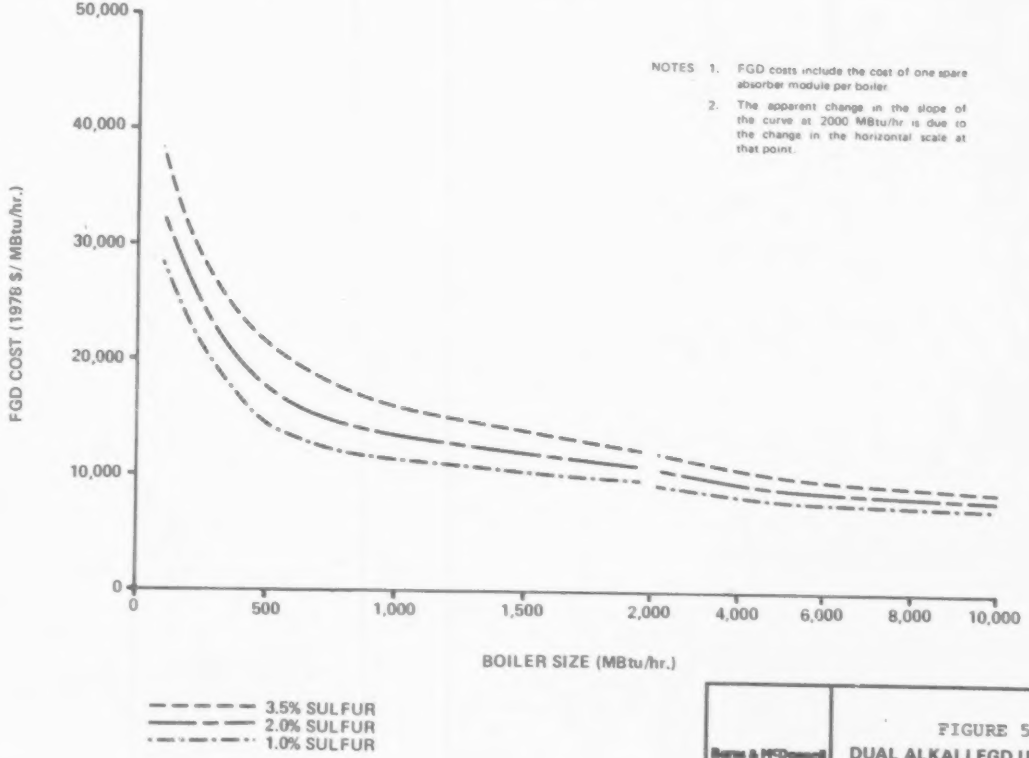


NOTES: 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

FIGURE 4

DUAL ALKALI FGD UNIT COSTS AT 90% SO2 REMOVAL



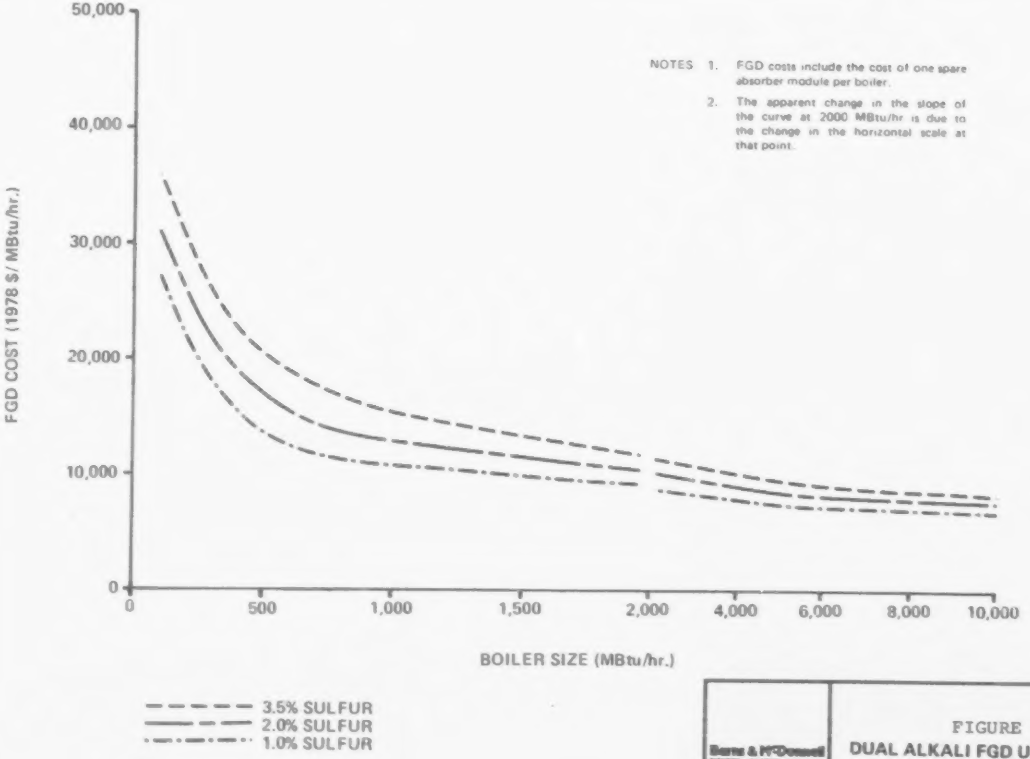
NOTES 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

Burns & McDonnell

FIGURE 5

DUAL ALKALI FGD UNIT COSTS AT 70% SO2 REMOVAL

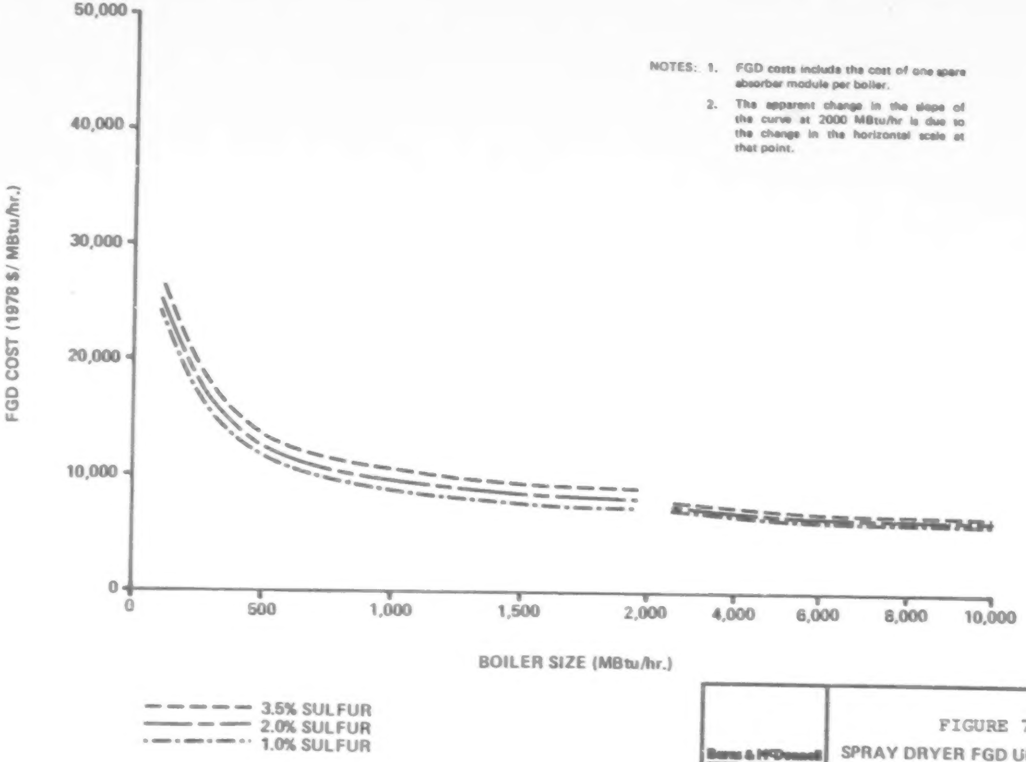


NOTES 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

FIGURE 6

DUAL ALKALI FGD UNIT COSTS AT 50% SO2 REMOVAL



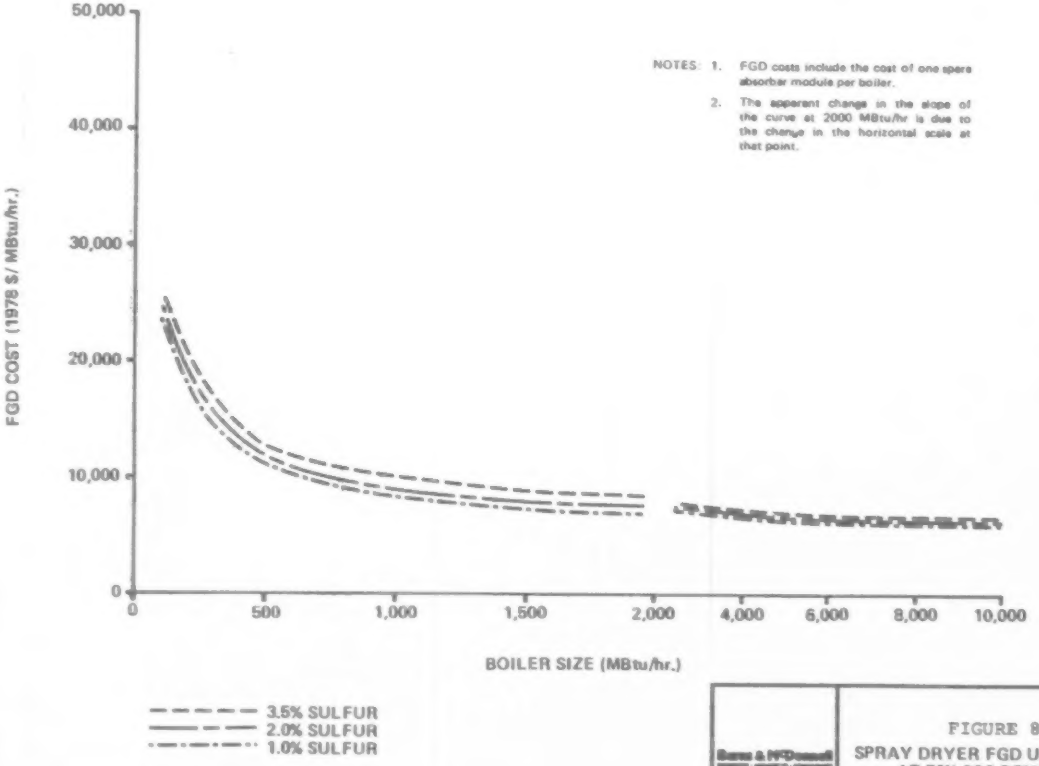
NOTES: 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

Burns & McDonnell

FIGURE 7

SPRAY DRYER FGD UNIT COSTS AT 90% SO2 REMOVAL

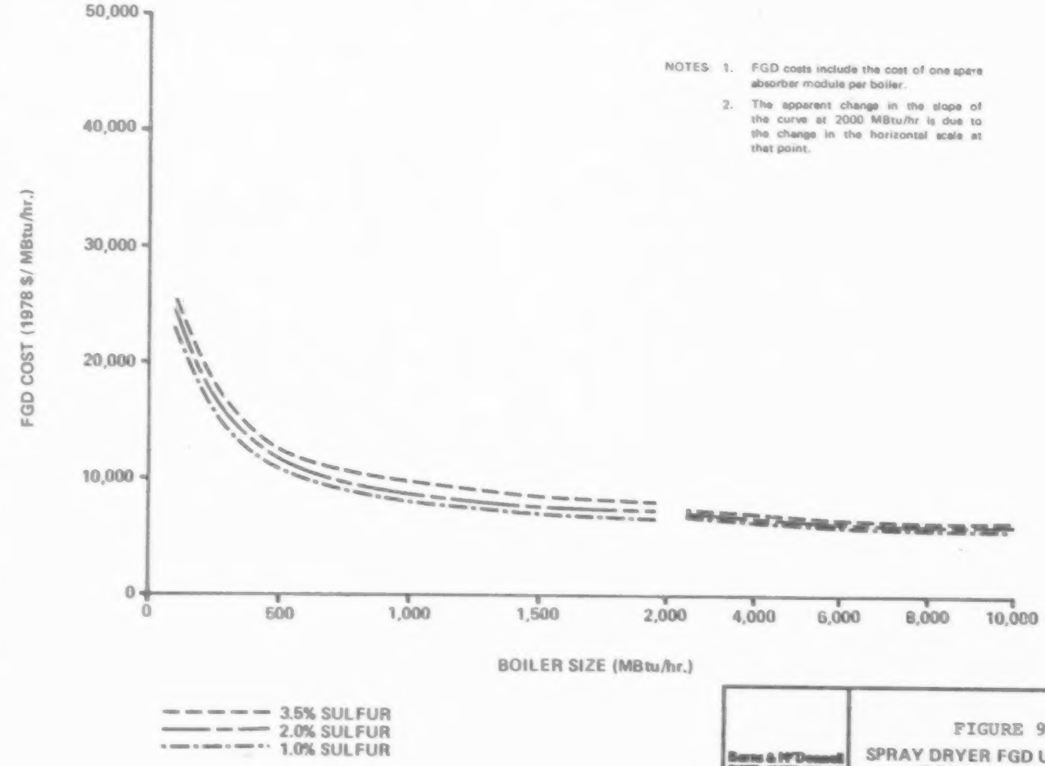


NOTES: 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

FIGURE 8

SPRAY DRYER FGD UNIT COSTS AT 70% SO2 REMOVAL



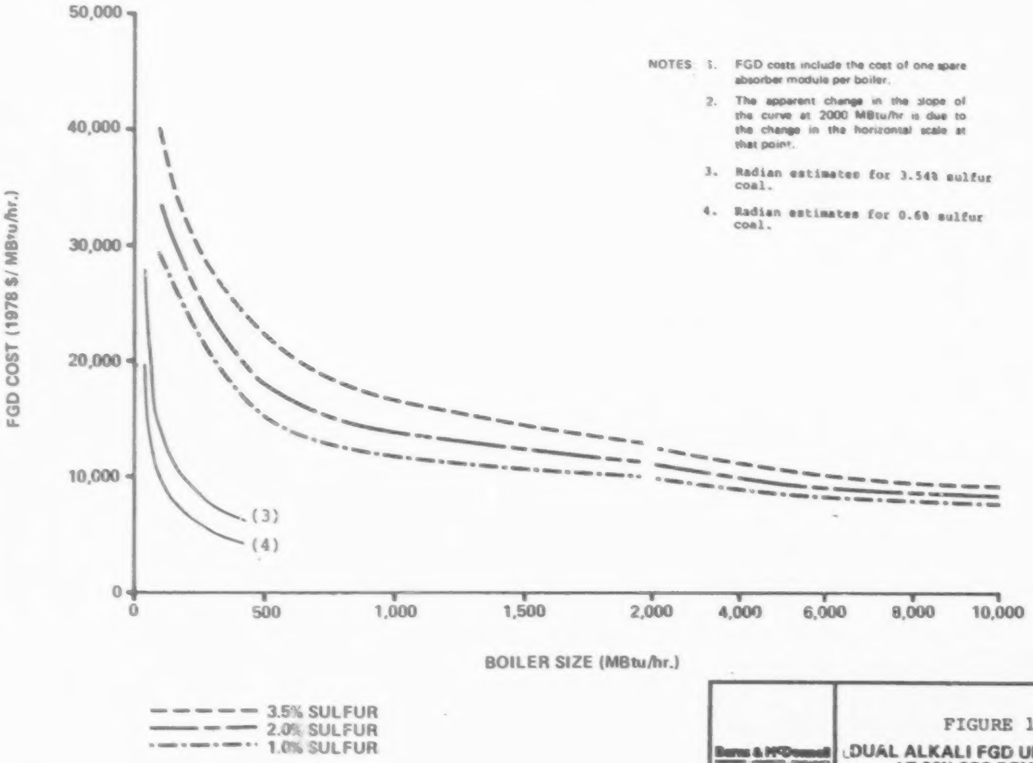
NOTES 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

Burns & McDonnell

FIGURE 9

SPRAY DRYER FGD UNIT COSTS AT 50% SO2 REMOVAL



NOTES 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

3. Radian estimates for 3.54% sulfur coal.

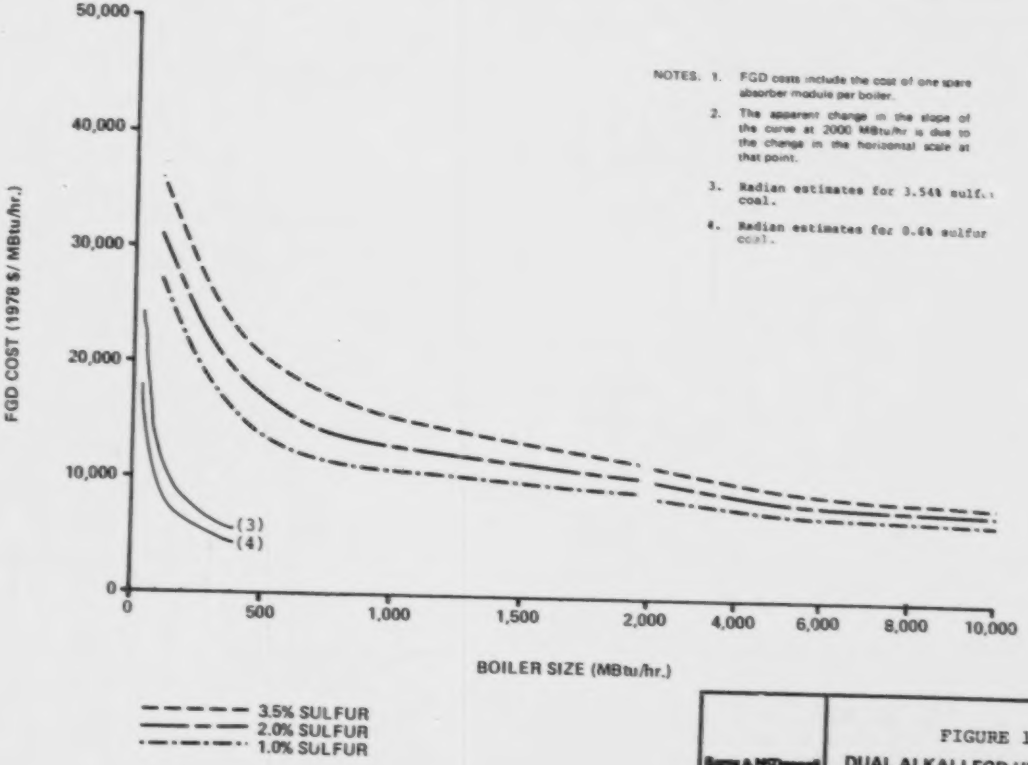
4. Radian estimates for 0.6% sulfur coal.

Burns & McDonnell

FIGURE 10

DUAL ALKALI FGD UNIT COSTS AT 90% SO2 REMOVAL

WITH COMPARISON TO RADIAN COST ESTIMATES



NOTES. 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

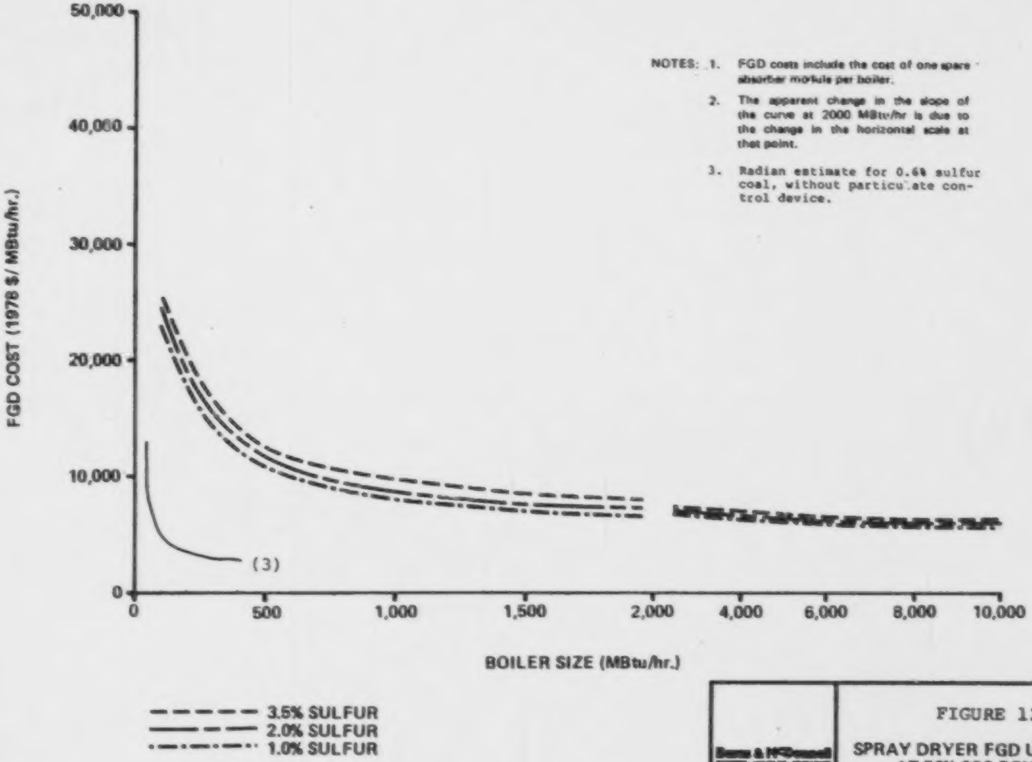
3. Radian estimates for 3.54% sulfur coal.

4. Radian estimates for 0.6% sulfur coal.

FIGURE 11

DUAL ALKALI FGD UNIT COSTS AT 50% SO2 REMOVAL

WITH COMPARISON TO RADIAN COST ESTIMATES



NOTES: 1. FGD costs include the cost of one spare absorber module per boiler.

2. The apparent change in the slope of the curve at 2000 MBtu/hr is due to the change in the horizontal scale at that point.

3. Radian estimate for 0.6% sulfur coal, without particulate control device.

FIGURE 12

SPRAY DRYER FGD UNIT COSTS
AT 50% SO2 REMOVAL
WITH COMPARISON TO RADIAN
COST ESTIMATES

American Iron and Steel Institute

1000 16th Street N.W., Washington, D.C. 20036

Earle F. Young, Jr.
Vice President
Energy and
Environment
(202) 452-7271

April 27, 1984

The Honorable James A. McClure
Chairman
Committee on Energy and Natural Resources
United States Senate
Washington, D. C. 20510

Dear Senator McClure:

Statement of American Iron and Steel Institute
for the record in connection with
April 30, 1984 hearing on
Implementation of the
Acid Precipitation Act
of 1980

In response to your letter of April 16, 1984, the American Iron and Steel Institute (AISI) submits the following comments relative to the Acid Precipitation Act of 1980 (Subtitle A of Title VIII of the Energy Security Act, P.L. 96-294). The American Iron and Steel Institute is the principal trade association of the steel industry; its 57 domestic member companies account for almost 90% of the steel production capability in the United States.

The steel industry has both direct and indirect economic interests in the acid rain debate. Proposed acid rain control measures will significantly increase the cost of electricity to the steel industry. The steel industry, which consumes 40 to 60 billion kilowatt hours per year is one of the largest consumers of electricity in the United States. Our purchases represent about 2½ percent of all the energy produced by the nation's utilities. Therefore, an acid rain control program which affects utility rates could have a significant adverse impact on the steel industry during this critical, financially distressed period. A study conducted for AISI by ICF Incorporated of a range of acid rain legislative proposals estimated that steel industry electricity costs alone could increase up to $164 million per year. Because electricity cost increases spread pervasively throughout the economy, one or more layers of such increments will be passed through to steel operations as further escalation of goods and services. Furthermore, the higher range of proposed sulfur oxide emission cutbacks could result in additional expenses for reduction of sulfur emissions from steel plant operations. Some industry estimates indicate this could result in additional steel industry capital expenditure requirements of $300 million plus an additional $100 million annual cost for control.

In view of this potential impact on our industry from proposed acid rain control programs, the industry has been following closely the progress of research on the causes and effects of acid precipitation and possible remedial actions. Based on our analysis of the reports of the National Acid Precipitation Assessment Program, the National Research Council, the United States Geological Survey, and other public and private bodies, we have developed the following comments on the specific questions in your letter relative to scientific knowledge.

A. Causes and Effects of Acid Precipitation

1. Causes

It is generally accepted today that manmade emissions of sulfur oxides and nitrogen oxides are the primary source for increased acidification of rainfall in the northeastern United States. However, the chemical changes and rates of reactions required to convert these gaseous emissions into the acidic sulfates and nitrates in deposition are not well understood. They are the subject of extensive research today. An even greater unknown today is the quantitative relation between emissions from specific sources and deposition on receptors. The National Academy of Research report says, "There is admittedly much to be learned about the relationships between emissions and depositions." The report goes on to emphasize, "[T]he relative importance for deposition at a specific site of long range transport from distant sources as compared with more direct influences of local sources cannot be determined from currently available data or reliably estimated using currently available models."

2. Effects

The major damages attributed to acid rain are adverse effects on the ecology of lakes, rivers, and streams. There is evidence that acid rain is related to the acidification or increased acidity in lakes and streams with no alkalinity. Quantitatively, however, acidity trends in surface waters have been difficult to estimate. In the Northeast, between the 1930s and 1970s, it appears that there may have been a decrease in pH and an increase in acidity in some water bodies, particularly in areas of low buffering capacity. Some reports clearly say that there has been acidification of a number of lakes and streams in the northeastern U.S. and eastern Canada. The number of such lakes has been estimated in hundreds, yet the area of affected waters is only of the order of 4 percent of the surface area of lakes in the Adirondacks. In addition, a recent U.S. Geological Survey report examining ten to fifteen years of water quality records from a network of headwater sampling stations showed a substantial decline in streams' sulfate concentrations in the northeastern sections of the United States. That study also indicated that the pH levels in the northeastern quadrant were, for the most part, in spite of the decrease in sulfates, unchanged for the period of the study and, in some cases, slightly decreased. These data tend to refute statements that the acidity of northeastern streams is increasing.

Other areas of suspected effects include forests and crops, materials, and human health. There is evidence of some deterioration of forests, but the role, if any, of acid rain has not been positively identified. Experience in both Europe and North America has shown that air pollutants do hasten the deterioration of buildings, statues, and other materials, but the part played by acid precipitation in the degradation of materials is still recognized as a major unknown. Health risks to humans are believed to be very low, perhaps none at all, at present levels of acid deposition. In all of these areas, more scientific knowledge and more research are needed.

B. Adequacy of Research Plans

Much excellent work is in progress or planned to attack the specific problems identified. Uncertainties in source-receptor relationships are being addressed by massive tracer experiments involving a number of organizations including Department of Energy, U.S. EPA, NOAA, EPRI, and the Canadian Atmospheric Environment Service. The National Acid Precipitation Assessment Program with its budget of $55 million is examining mechanisms of deposition, the resources at risk from deposition, environmental responses and surveys of the nation's lakes and forests. We would say that the programs now in effect will provide answers to the problem of acid rain.

C. Consensus on Solutions to the Problems

There seems to be some agreement that a primary means for controlling acid precipitation, if such controls are needed, would be to reduce sulfur oxide and nitrogen oxides emissions. There is no agreement, however, on the need for immediate action, the urgency of prompt action, the magnitude of emissions reductions that are necessary, the locations from which emissions need to be controlled, or the proper source of funding for these controls.

D. Adequacy of Knowledge as a Basis for Regulations

We believe that the uncertainties in the knowledge of the effects of acid rain on the environment and particularly of source-receptor relationships outlined above are so great that it is impossible today to devise any regulatory program which would have identifiable benefits. Regulation which would only hope to be beneficial cannot be justified considering the costs and dislocations involved.

E. Consequences of Premature Regulatory Action

Estimates of the annual costs of emission reductions under various proposed acid rain programs range from about $2.5 billion to $8 billion. Depending on the form of regulations, there could be very significant employment dislocations among midwestern and eastern coal miners. Family utility rate increases in some states are estimated to range from $100 to $450 per year. Increased costs to industry would be staggering. We would, therefore, strongly recommend no regulatory program until further research better defines the need for such a program, the benefits to be gained, and the effective means of implementing it.

With regard to the legislative proposals before the Congress, it is our belief that legislative proposals and positions generally reflect regional and state interest. Midwestern congressmen whose states would be required to achieve the greatest emission reduction question the need for acid rain controls or favor national cost sharing. In states where employment in the high-sulfur coal industry would suffer, tremendous pressure has been brought to bear to insure that jobs would be protected by mandating the installation of scrubbers, thus reducing a major incentive for the use of low-sulfur coal. Western representatives whose states have large reserves of low-sulfur coal are generally opposed to mandated scrubbers. It is our belief that none of the present proposals provides a national solution, considering all the technical, economic, political, and social issues enveloping the acid rain debate. AISI believes that the most appropriate legislation at this time should support an accelerated research program directed at answering the questions raised above, along with modest direct action to mitigate the acidic conditions found in some northeastern lakes.

We are happy to provide these comments to assist the committee in its oversight on implementation of the Acid Precipitation Act of 1980. If you have any additional questions or wish additional information from us, please feel free to call on AISI.

Very truly yours,

E.F. Young, Jr.

E. F. Young, Jr.

:jsn

COUNCIL OF INDUSTRIAL BOILER OWNERS

PRESIDENT
William B. Marx

May 10, 1984

The Honorable James A. McClure
Chairman, Committee on Energy and
Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

We very much appreciate being invited to comment on the Acid Precipitation Act of 1980 and the National Acid Precipitation Assessment Program established under its provisions. In addition to this letter, we transmit herewith, copies of the following pertinent documents:

1. November 1983 CIBO Statement Before the Senate Environment Committee on S. 768, the Clean Air Act Amendments of 1983;
2. March 1984 CIBO Statement Before the House Subcommittee on Health and the Environment on H.R. 3400, the Clean Air Act Amendments of 1984;
3. Fifteen case histories which detail the impact on industry of an emissions cap, such as that contained in many of the legislative proposals before Congress.

The State of Scientific Knowledge

CIBO believes that existing scientific evidence is inadequate and the processes involved insufficiently understood to allow the design of an effective acid rain control program at the present time. There are many fundamental questions that remain unresolved regarding the acid rain problems, including such matters as the importance of local versus distant sources, the relative role of acidic deposition in the rate of acidification of the environment, and the impact of such acidification on biological activity.

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As to the role of acidic deposition in the overall acidification of the environment, it deserves emphasis that biological acidification is the normal course of events in the environment. Biological decay invariably produces organic acids; thus, floral and faunal litter in the fields and forests is a significant contributor to acidification. Moreover, the normal weathering of soils frequently produces acidification. Accordingly, it has been estimated by soil scientists that acidic deposition in the Northeast contributes, depending on the pH of the rainfall, less than 20%, and probably less than 5%, of the total acidification occurring in soils, streams and lakes of that region.

Furthermore, acidic deposition has been going on at faster or slower rates than the current rate for millions of years. There are ample records in the glaciers of Greenland that show a close correlation between acidity and known or geologically identified periods of volcanism. Thus, between normal environmental sources of acidification and uncontrollable natural sources of acidic deposition, there has always been acidification of the environment.

As to the impact of such acidification, there have been many assertions that acidic deposition is responsible for forest damage, most of which is unsupported by scientific demonstration. However, there is now fast accumulating scientific evidence that other environmental factors play more important roles in those situations where forest problems are occuring. For example, certain other air pollutants not the result of combustion processes, particularly photochemical oxidants; and natural phenomena such as disease, insect attack, poor mineral nutrition, and drought have now been shown to have contributed significantly to the spruce forest problems of the Northeast, as well as to recent problems in the forests of Germany, Switzerland and Scandinavia. These studies show, in fact, that neither acidic deposition nor acidification can be consistently correlated with these forest problems.

Thus, we do not feel that current knowledge is adequate to permit substantive regulatory decisions and that substantial additional research must be completed first. It is our strong belief that this is the consensus of industrial fuel users as represented by CIBO member companies.

It should be obvious to all concerned that research must be the cornerstone of our program to identify cause and effect relationships. Premature regulatory action based on uncertain scientific analysis inhibits the making of sound economic decisions by business with the following deleterious economic, energy and environmental effects:

1. Hamper expansion, limit efforts to increase productivity and reduce industrial competitiveness;
2. Dampen industry's move onto coal;
3. Retard the development of several promising emerging SO_2 and NO_x control technologies which may be suitable for industrial applications.

Finally, it cannot be overemphasized that premature regulation runs the strong risk of being wasteful and costly. In the longer run it will be less effective since it will dampen development and thus freeze technology, place heavy reliance on today's expensive scrubbers and delay the use of the more cost-effective technologies now emerging.

In this context each dollar spent now to bring these emerging and innovative technologies into commercial use will be returned many times.

Because of its convictions and in order to assist the resolution of these issues, CIBO has held meetings with members of the Interagency Task Force on Acid Precipitation, Department of Energy and Environmental Protection Agency, as well as Chairman A. Alan Hill of the Council of Environmental Quality and Assistant Secretary for Fossil Energy, William A. Vaughan. As a result we have determined that our participation should be concentrated in the various programs of Task Group B, Man-Made Sources; Task Group H, Control Technologies; and Task Group I, Assessments and Policy Analysis. The final step in this process is our current effort to design a program which will relate the various technical resources of CIBO member companies to these three program areas, on a project-by-project basis.

Thus we believe the organization will be able to contribute to the Energy Committee's ongoing oversight, perhaps on a more specific basis in the future.

Legislative and Regulatory Proposals

Most of the proposals now before Congress would strongly retard accelerated industrial coal use. Moreover, many of the bills contain provisions for an emissions "cap". Ironically, such a cap, based on some past emissions rate, i.e., a "roll back", would impact most adversely those very plants which have aided achievement of an important national energy goal through recent increased coal use. In fact, the number of recently installed coal-fired boilers potentially facing exposure to this onerous requirement is large, over 200. They represent 11 two-digit SIC industrial groups and are located in 24 states of the "long-range transport corridor".

S. 768 also would impose an emissions cap on nitrogen oxides. This will exacerbate the bias against coal use, since the higher ratio of NO_x emissions over oil or gas (7:3:2) would in effect bar increased industrial coal use and thus cause reconversion away from coal in some plants and stifle new coal projects in others. In some cases it could well lead to plant shutdown. Furthermore, because of the emerging NO_x control technologies and the lack of understanding of the role played by NO_x in the formation of acid precursors, referred to above, such a limitation is especially inadvisable now.

It should be noted that the recent marked increase in the use of waste fuels by industry would be curtailed, since these fuels may have higher rates of NO_x formation than gas or oil. This could actually increase SO_2 emissions, since most of these displaced waste fuels contain very small amounts of sulfur. Equally detrimental to the nation's energy and economic well-being would be their effect to severely limit industrial fuel flexibility, restricting a plant's capacity to manage fuel supply interruptions, with potential damaging effects to production, employment and national defense.

With regard to the cost of electricity, unless control legislation is confined to utility sources, the financial burden of industry through direct compliance costs and increased electricity rates will indeed be exorbitant. Electricity used by industry in 1981 totaled 2.85 quads of electrical energy at a cost of $37 billion. At a forecasted average industrial rate increase of anywhere from 15-65%, industry automatically will pay its share of added utility control costs. Furthermore, to impose direct control costs on smaller industrial sources would not be cost-effective for the consumer.

With regard to their environmental impact, industrial boilers are relatively minor contributors to the air inventory of sulfur dioxide. In fact, in 1981 industrial boilers consumed less than 10% of the nation's total coal use. From now until 1995, this industrial coal use is expected to expand only by approximately 4% annually. Underscoring this modest impact of industrial boilers, is a recent State of Pennsylvania study showing that even with maximum feasible increased industrial coal use, the added SO_2 emissions would only affect the present SO_2 inventory by 1.2% in that state.

Accordingly, the untimely imposition of additional controls on industrial boilers would be doubly unfortunate.

Finally, such proposals will retard the development of emerging SO_2 and NO_x control technologies for industrial applications. In this connection, please carefully review Case History #4 in which a new technology, fluidized bed combustion "which will result in energy conservation and very low air pollution emissions will not be permitted to commence operation because emission offsets are not available in Louisiana". Thus, introduction of this promising solid fuel-burning technique into one of the nation's most energy intensive industries, pulp and paper, is being retarded and could be prevented. This is a dramatic example of the interfaces between science-technology, control legislation and public policy.

Conclusion

In conclusion then, CIBO would support the several legislative proposals now before Congress which call for accelerated research. Most beneficial to industrial fuel users would be efforts in the following areas:

- Integration of results from private sector emission control technology programs already underway.
- Analysis of NO_x emissions and their relative contribution.
- Development, demonstration and evaluation of SO_2 and NO_x control technologies.
- Assessment of the relative cost-effectiveness of various SO_2 and NO_x technologies.

Thank you for this opportunity to present our views, and we look forward to working with your committee on these issues in the future.

Sincerely,

William B. Marx

William B. Marx
President
Council of Industrial
Boiler Owners

WBM:mm

Enclosures (4)

COUNCIL OF INDUSTRIAL BOILER OWNERS

PRESIDENT
William B. Marx

TESTIMONY
ON BEHALF OF THE
COUNCIL OF INDUSTRIAL BOILER OWNERS
BY
J. C. SCHWEGMANN, MANAGER OF AIR SERVICES,
KAISER ALUMINUM AND CHEMICAL CORPORATION
ON
CLEAN AIR ACT AMENDMENTS OF 1983 (S. 768)
BEFORE THE
COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE
November 17, 1983

Introduction

I am J. C. Schwegmann, Manager of Air Services, Kaiser Aluminum and Chemical Corporation and a member of the Environmental Committee of the Council of Industrial Boiler Owners ("CIBO"). I am accompanied by William B. Marx, president and James P. Rathvon, CIBO counsel.

CIBO is a broad-based association of industrial boiler operators and related equipment manufacturers, representing sixteen major industries, independent of public utilities. CIBO was formed in 1978 to encourage the maximum exchange of relevant information among its members and between industry and government to assure that public policy in fuel utilization and environmental areas is realistic in light of the contribution to our economy of industrial boiler users and their support of the free market.

Scope of Testimony

Because our interests are confined to issues relating to industrial steam generation, we will limit our comments to those provisions in the bill which would affect fuel use in industrial boilers. These are as follows:

A. Sec. 182 - "Research and Special Studies"
B. Sec. 183 - "Acid Precursor Controls"
C. Sec. 186 - "Major Stationary Source Reduction Requirements"

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Specific Comments

A. Sec. 182 - "Research and Special Studies"

- Sections 182(a) through (f) include stages of review by the Acid Precipitation Task Force, the Acid Precipitation Scientific Review Board, the Office of Technology and Assessment and the EPA. CIBO urges that the public sector be invited to participate in this process to assure that fuel burning industries, designers and manufacturers are able to contribute their specialized knowledge in our search for practical solutions.

- Section 182(c)(1) requires that the Acid Precipitation Task Force ". . . shall also conduct and support research on advanced flue-gas cleaning and precombustion fuel treatment technologies and inherently low-emission combustion processes. . . ."

  This is an important and beneficial provision since there are many promising emerging technologies for burning coal, which remove acid precipitation precursors, before, during and after combustion which such research should be encouraged.

- CIBO strongly supports the provisions of 182(e)(2) which require that an assessment be made of benefits and costs associated with planned actions before they are implemented, and 182(f) which calls for hearings by the Congress to provide a basis for further action. CIBO believes that this study will reflect the fact that was stated in the National Academy of Sciences report, "Acid Deposition; Atmospheric Processes in Eastern North America", "It can be stated as a rule of thumb that the farther a source is from a given receptor site, the smaller its influence on that site will be per unit mass emitted." Only by identifying the relative impact of all sources will it be possible to develop cost-effective and equitable control of pollutants."

- Section 182(g) requires the Administrator to (1) develop an inventory of nitrogen oxide ("NO_x") sources; (2) report on control technologies; and (3) make possible control recommendations.

Because the role of NO_x as a potential precursor to acid deposition is not well understood, and since NO_x emission control technologies are in the early stages of development, we support this provision.

B. Section 183 - "Acid Precursor Controls"

While CIBO believes that the scientific evidence does not support the need for controls or the specific provisions of this legislation, any control strategy should include the most equitable cost-effective solutions.

- Cost Effectiveness - Because of their small size, stringent control of industrial boilers is not cost-effective. Thus, the imposition of such direct control requirements could result in excessive costs to the public, in most cases three to four times greater than those resulting from control of very large sources.

- Equitable Burden - Electricity used by industry in 1981 totalled 2.85 quads at a cost of $37 billion. Thus, at a forecast average industrial rate increase of at least 15%, control measures imposed on the utility industry will result in an industrial cost increase of more than $5 billion annually, which must be added to the cost of products and services bought by the public. Added to this financial burden, of course, will be any direct industrial control costs.

- Air Quality Impact - In 1981 industrial boilers consumed less than 10% of the nation's total coal use. During the next 10-12 years this industrial coal use is widely predicted to expand by no more than 3% annually, with a corresponding small increase in SO_2 emissions. Underscoring this modest impact is a recent State of Pennsylvania study showing that even with maximum feasible increased industrial coal use, the added SO_2 emissions would only affect the present SO_2 inventory by 1.2% in that state..

The need for cost-effective and equitable action is of vital concern to the industrial steam producer as well as to other fuel burning and energy using segments of industry. Severe and expensive controls which produce little environmental improvement in the so-called sensitive areas are likely to occur under the present legislative proposal. Although the scientists who produced the National Academy of Sciences report on Acid Deposition were unable to assign specific values to the role of the various sources, both nearby and remote, they clearly indicate that both size of source and proximity to the receptor help determine the benefit of any reduction in emissions. Thus, widespread and stringent emission reductions without proper regard to these factors will produce inequitable burdens on these sources whose impacts are already small.

Furthermore, any mandated specific control methods based on uncertain scientific analysis would inhibit the making of sound economic decisions by business with the following deleterious economic, energy and environmental effects:

1. Hamper expansion, limit efforts to increase productivity and reduce industrial competitiveness;

2. Dampen industry's move back onto coal, and away from imported oil;

3. Retard the development of emerging SO_2 and NOx control technologies for industrial applications.

4. Injure the long-term competitive position of U.S. industry.

Sections 183(b) and (c) provide for an SO_2 emissions "cap" based on actual 1980 emissions. This will be particularly harmful in that it will:

1. Bar increased industrial coal use.

2. Severely limit industrial fuel flexibility, restricting a plant's capacity to manage fuel supply interruptions, with potential damaging effects to production, employment and national defense.

3. Impose a second layer of control on new sources, already required to meet the complex NSPS or BACT standards.

4. Set an artificial limit on plant production.

Ironically, a cap based on some past emissions rate, i.e., a "roll back", would impact most adversely those very plants which have aided achievement of an important national energy goal through recent increased coal use. In fact, the number of recently installed coal-fired boilers potentially facing exposure to this onerous requirement is large, over 200. They represent 11 two-digit SIC industrial groups and are located in 24 states of the "long range transport corridor." This statement applies equally to any NO_x emissions cap, too.

(Note: CIBO will submit a number of these case histories for the record.)

In effect, this provision also would discriminate against certain regions. Any emission offsets for new sources particularly discriminates against states that do not have older industry from which to seek offsets, or states where industrial growth is occurring rapidly, e.g., the southern states.

Section 183(e) would impose an emissions cap on nitrogen oxides. This will exacerbate the bias against coal use, since the higher ratio of NOx emissions over oil or gas (7:3:2) would in effect bar increased industrial coal use and cause reconversion away from coal in some plants. Furthermore, because of the emerging NOx control technologies and the lack of understanding of the role played by NO_x in the formation of acid precursors, referred to above, such a limitation is especially inadvisable now. Thus, control strategies developed now and in the near future should be limited to SO_2 emissions until these NOx control processes are commercially demonstrated for industrial use.

It also should be noted that the recent marked increase in the use of waste fuels by industry would be curtailed, since most of these fuels have higher rates of NO_x formation than gas or oil. This could actually increase SO_2 emissions, since most of these displaced waste fuels contain very small amounts of sulfur.

Section 183(e) also affords an exemption for utility boilers defined as "coal capable" under the Fuel Use Act. If they are to be covered, industrial boilers should also be granted such an exemption.

The Percentage Reduction Requirement

Finally, CIBO believes that any Clean Air Act Amendment should include the repeal of the percentage reduction requirement as it applies to industrial boilers. This requirement is not a suitable or cost-effective way to control sulfur emissions from industrial boilers. Mandating the use of scrubber systems would greatly increase the cost of industrial coal use, increase energy consumption by a factor of two to three, and increase boiler house manpower requirements substantially while providing minimal air quality improvement.

Closing

CIBO believes that today the Nation does not have the data nor the understanding to put in place an effective acid deposition control program. Recent studies, notably the National Academy's "Acid Deposition; Atmospheric Processes in Eastern North America", make it clear that today it is not possible to identify the specific change in the acid deposition patterns that would result from a given change in precursor emissions, nor to determine the specific importance of local sources and long-range transport. As a consequence, CIBO states its belief that these undertainties make it virtually impossible for Congress to legislate equitable and cost-effective solutions to this problem at present.

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COUNCIL OF INDUSTRIAL BOILER OWNERS

PRESIDENT
William B. Marx

TESTIMONY
ON BEHALF OF THE
THE COUNCIL OF INDUSTRIAL BOILER OWNERS
BY
J.C. SCHWEGMANN, MANAGER OF AIR SERVICES
KAISER ALUMINUM & CHEMICAL CORPORATION
ON
CLEAN AIR ACT AMENDMENTS OF 1984 (H.R. 3400)
BEFORE THE
SUBCOMMITTEE ON HEALTH AND THE ENVIRONMENT
COMMITTEE ON ENERGY AND COMMERCE
UNITED STATES HOUSE OF REPRESENTATIVES

March 29, 1984

I am Dr. Jack Schwegmann. I am an environmental biologist and administrator with more than 30 years of full-time experience. I am presently serving as Manager of Air Services in the Corporate Environmental Affairs Department of Kaiser Aluminum & Chemical Corporation. Kaiser Aluminum is a member of the Council of Industrial Boiler Owners (CIBO). I am accompanied by William B. Marx, President of CIBO, and Jan B. Vlcek, CIBO counsel.

CIBO is a broad-based association of industrial boiler operators and related equipment manufacturers, representing nineteen of the twenty most energy-intensive U.S. industries, independent of public utilities. CIBO was formed in 1978 to encourage the maximum exchange of relevant information among its members and between industry and government to assure that federal energy and environment policies are reasonable and realistic in light of the importance of industrial steam generation to our economy. Thus, our interests in H.R. 3400 are confined to issues relating to the generation of steam by industrial boilers.

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In brief, CIBO believes that the scientific evidence does not justify an acid rain control program. Furthermore, CIBO is concerned that passage of H.R. 3400 would impose excessive costs on the public for minimal environmental benefit, hamper expansion of our economy, and dampen industry's move back to coal and away from imported oil.

I. Scientific Evidence Does Not Justify Controls

CIBO believes that existing scientific evidence does not justify an acid rain control program. Currently, there are many fundamental questions that remain unresolved regarding the acid rain problem, including such matters as the importance of local versus distant sources, the relative role of acidic deposition in the rate of acidification of the environment, and the impact of such acidification on biological activity.

As an environmental biologist, I have followed the scientific research into these issues with great interest. Here, I wish to draw attention to a few points from this research that are sometimes overlooked in the acid rain debate.

First, as to the role of acidic deposition in the overall acidification of the environment, it deserves emphasis that biological acidification is the normal course of events in the environment. Biological decay invariably produces organic acids; thus, floral and faunal litter in the fields and forests is a significant contributor to acidification. Moreover, the normal weathering of soils frequently produces acidification. Accordingly, it has been estimated by soil scientists that acidic deposition in the Northeast contributes, depending on the pH of the rainfall, less than 20%, and probably less than 5%, of the total acidification occurring in soils, streams, and lakes of that region.

Furthermore, acidic deposition has been going on at faster or slower rates than the current rate for millions of years. There are ample records in the glaciers of Greenland that show a close correlation between acidity and known or geologically identified periods of volcanism. El Chichon volcano in Mexico, for example, is estimated to have produced up to 9 million tons of SO_2 in a single eruption event in 1982. El Chichon has been estimated to have produced a total of 20 million tons of sulphate and the resulting sulfate cloud is still contributing to the current rate of acidic deposition. Thus, between normal environmental sources of acidification and uncontrollable natural sources of acidic deposition, there has always been acidification of the environment.

As to the impact of such acidification, there have been many assertions that acidic deposition is responsible for forest damage, most of which have been anecdotal, that is, unsupported by scientific demonstration. However, there is now fast accumulating scientific evidence that other environmental factors play more important roles in those situations where forest problems are occurring. For example, other air pollutants, particularly photochemical oxidants, and natural phenomena such as disease, insect attack, poor mineral nutrition, and drought, have now been shown to have contributed significantly to the spruce forest problems of the Northeast, as well as to recent problems in the forests of Germany, Switzerland, and Scandinavia. These studies show, in fact, that neither acidic deposition nor acidification can be consistently correlated with these forest problems.

Given the substantial uncertainties regarding the causes and effects of acid deposition, CIBO strongly believes that further research should be conducted to determine whether a massive and costly program to control acid rain should be launched by Congress.

II. Environmental Control Programs Should be Cost-Effective and Equitable

If, notwithstanding these scientific questions, such a program were imposed, it is CIBO's position that it should reflect certain basic considerations to avoid unnecessary burdens on the economy.

We believe that any acid rain control program should be targeted to sources that have the greatest likelihood of reducing acid deposition in the receptor areas. As noted by the National Academy of Sciences in its Report last summer, "It can be stated as a rule of thumb that the farther a source is from a receptor site, the smaller its influence on that site will be per unit mass emitted." This principle suggests that any controls that are imposed should focus on sources on the basis of their real potential to achieve reduction of acidic deposition in the sensitive areas.

Although H.R. 3400 does target the 50 largest emitters, it does so regardless of location. Moreover, the new Subpart 2 added by H.R. 3400 requires states to impose additional controls on individual sources, potentially including industrial boilers, regardless of their size or proximity to the sensitive areas. CIBO believes that additional controls on industrial boilers would be counterproductive for several reasons:

- o Lack of Cost-effectiveness - Stringent controls of industrial boilers are not cost-effective because of their small size. In fact, the cost of removal of a pound of sulfur dioxide from a typical industrial boiler is three to five times as great as that from very large sources. Thus, direct controls on industrial boilers would impose excessive costs on industry and the public.
- o Severe Financial Burden - Industrial boiler users are major customers of utilities. In fact, electricity used by all of industry in 1981 totalled 2.85 quads at a cost of $37 billion. Thus, even at a forecasted annual average industrial rate increase of 15%, control measures imposed on the utility industry will result in an industrial cost increase of more than

$5 billion annually, which must be added to the cost of products and services bought by the public. In addition to this financial burden which we would bear as ratepayers, we would also bear the costs of any further direct controls on our industrial boilers.

- Relatively Small Air Quality Impact - Industrial boilers are relatively minor contributors to the air inventory of sulfur dioxide. In fact, in 1981 industrial boilers consumed less than 10% of the nation's total coal use. From now to 1995, this industrial coal use is expected to expand only by approximately 4% annually. Underscoring the modest impact of industrial boilers is a recent State of Pennsylvania study showing that even with maximum feasible increased industrial coal use, the added SO_2 emissions would only affect the present SO_2 inventory by 1.2% in that state. Accordingly, the environmental benefit from additional controls on industrial boilers would be modest even under the most severe control scenario.

In light of these considerations, CIBO is strongly opposed to direct acid rain controls on industrial boilers. CIBO believes that such controls would be extremely costly and provide little environmental benefit. And, they would discourage U.S.

industry from increasing its utilization of coal and thus would be counterproductive to the effort to reach the Nation's energy goals. In short, such controls must be avoided.

III. An Emissions Cap

While H.R. 3400 does not provide for an emissions cap, we would offer our comments on such a proposal, particularly as contained in certain other House and Senate bills. CIBO is strongly opposed to an emissions cap. Inclusion of such a cap would seriously hamper industrial expansion, particularly in regions with little available offset opportunities, and would further discourage increased use of coal. In fact, a cap retroactive to 1980 could result in the closing of many recently constructed plants. Accordingly, CIBO urges the Subcommittee to resist any proposals to add an emissions cap to H.R. 3400.

IV. Elimination of the Percentage Reduction Requirement

Finally, CIBO believes that any Clean Air Act amendment should include the repeal of the percentage reduction requirement as it applies to industrial boilers. This requirement is not a suitable or cost-effective way to control sulfur emissions from industrial boilers. The use of scrubber systems greatly increases the cost of industrial coal use, increases energy consumption in the boiler house by a factor of two to three, and increases boiler house manpower requirements substantially. Moreover, because of energy conservation measures adopted by industry over the past several years, and the relatively low growth rate in the industrial sectors of the economy, there is currently an excess of industrial boiler steam capacity. Thus, most new boilers that will be installed in the foreseeable future will replace existing boilers. Therefore, the percentage reduction requirement, by requiring the installation of scrubbers, could actually retard progress toward cleaner air and energy conservation by discouraging the replacement of older, less efficient industrial boilers with new, efficient units. Accordingly, CIBO urges the repeal of the percentage reduction requirement for industrial boilers.

V. Conclusion

CIBO believes that today the Nation has neither the data nor the understanding to put in place an effective acid deposition control program. With research into the acid rain issue rapidly progressing, CIBO believes that further consideration of acid rain legislation is not warranted at this time. If such legislation is enacted, however, CIBO believes that it should focus on sources which impact the sensitive areas, be cost-effective, and be equitable to industrial boiler users.

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cibo
COUNCIL OF INDUSTRIAL BOILER OWNERS

December 20, 1983

PRESIDENT
William B Marx

Senator Robert T. Stafford
Chairman, Committee on Environment
and Public Works
410 SDOB
Washington, D.C. 20510

Dear Senator Stafford:

As a follow-up to our testimony of November 17, 1983 before your committee regarding the Clean Air Act Amendments of 1983 (S. 768), we are pleased to enclose additional information which we request be included in the hearing record.

On pages 4 and 5 of our testimony we pointed out that the imposition of an historical emissions cap would have the following deleterious effects:

- o Hamper expansion, limit efforts to increase productivity and reduce industrial competitiveness;
- o Dampen industry's move back onto coal, and away from imported oil;
- o Retard the development of emerging SO_2 and NOx control technologies for industrial application;
- o Injure the long-term competitive position of U.S. industry;
- o Impact most severely those companies which have recently increased their coal use;
- o Discriminate against certain regions.

We believe that the enclosed fifteen case histories demonstrate all of these points.

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Senator Robert T. Stafford
December 20, 1983
Page 2

Twelve of the cases are found in the southeast sector of the United States:

Louisiana	3	Kentucky	1
Alabama	2	Mississippi	1
Florida	2	South Carolina	1
North Carolina	2		

Note: Of the remaining 3 cases, 1 is in Idaho and 2 are in Michigan.

Seven of the 15 cases involve severe economic consequences:

- o Plant closure;
- o New plant - cancellation or delay;
- o Plant expansion - cancellation or delay;
- o Production cutbacks.

We believe these case histories further substantiate the conclusions set forth in our testimony.

Thank you for this opportunity of submitting additional information for the committee's consideration.

Sincerely,

William B. Marx

William B. Marx
President

WBM:mm
Enclosures (15)

ALTON

ALTON PACKAGING CORPORATION
A member of the Jefferson Smurfit Group
Mill Division Alton, IL 62002 • 618/463-6000

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TELEPHONE 904/353-3611

#1

December 5, 1983

Mr. William B. Marks
Council of Industrial Boiler Owners
11222 Silverleaf Drive
Fairfax Station, Virginia 22039

Dear Mr. Marks:

We reply to your questions asked in your letter of November 23, 1983, as follows:

1. When did your boiler go into service?
   May 1983
2. Required SO_2 emissions limit.
   .66 # per million BTU's
3. How SO_2 standard is met?
   Wet scrubber with second SO_2 stage in separator.
4. % sulfur in fuel?
   1 - 3.5%

Sincerely,

R. Burr

E. R. Burr
Manager of
Manufacturing & Engineering
Services - Mills

ERB:lab

CCA Container Corporation of America

500 East North Avenue
Carol Stream, Illinois 60187-2182

Phone 312 260-6700

#2 & #3

December 12, 1983

Mr. William B. Marx, President
Council of Industrial Boiler Owners
11222 Silverleaf Drive
Fairfax Station, VA 22039

SUBJECT: CIBO Acid Rain/Emissions Cap Survey
Your November 23, 1983 Letter

Dear Mr. Marx:

Thank you for the above letter. The subject of additional restrictive legislation on boiler emissions is of concern to us. We would appreciate being kept informed on the issue.

Answers to your four questions concerning our new power boilers are given below:

Question	BOILER No. 4	BOILER No. 7
1	September, 1981	December, 1982
2	1.2 lb/MM BTU	1.2 lb/BTU
3	Compliance Coal	Compliance Coal
4	0.75 to 1.5	0.75

Our Boiler No. 4 is a 390,000 lbs/hour, stoker-fired unit capable of burning any combination of wood waste and coal. Our Boiler No. 7 is a 770,000 lbs/hour, pulverized coal-fired unit. Both are located in attainment areas.

Sincerely,

Paul E. Trout

PAUL E. TROUT
Corporate Manager
Environmental Control

6123E/vs

#4

Acid Rain Legislation Impacts

Background: Crown Zellerbach has proposed the construction of a coal fluidized bed combustor cogeneration project at its St. Francisville, Louisiana Kraft Pulp and Paper Mill. The facility is designed to replace the existing low sulfur oil and gas fired boilers and provide lower cost electrical energy for the pulp mill.

The proposed advanced technology energy system is being reviewed by the Louisiana authorities for construction permits to meet Utility New Source Performance Standards and Prevention of Significant Deterioration regulations. Sulfur dioxide emission rates are expected to be 0.5 lb per million btu which is equivalent to 90% SO_2 removal. Control of NO_x would result in an emission rate of 0.12 lb/million btu which is 24% of the NSPS standard.

Proposed acid rain legislation (S. 769 and S. 145) would result in an emission cap on SO_2 and NO_x emissions. Any increase in emissions would require emission offsets.

Issue: Unless new or modified sources are exempted from the emission cap, new technology which will result in energy conservation and very low air pollution emissions will not be permitted to commence operation because emission offsets are not available in Louisiana.

Discussion: The Mitchell and Stafford bills as now drafted would probably prevent Crown Zellerbach from replacing their existing energy facilities at St. Francisville. Louisiana regulations have required the facilities to meet a low sulfur fuels standard for emissions (1.0 lb per million btu). There are no readily available offsets, such as in other midwest and eastern states where low sulfur fuels have not been required.

Conversion to a coal based energy system which can provide lower electrical and steam energy costs is necessary for the economic viability of the mill.

Conclusion: An emission cap on sulfur dioxide and nitrogen oxides on a state-by-state basis would result in severe economic constraints on production facilities in states such as Louisiana, which have required low sulfur fuels in the past. Generation of electrical energy from coal resources in efficient, lower emission facilities such as St. Francisville, should not be prevented.

DART & KRAFT

#5

Romer G. Wilsek
Director
Regulatory Affairs

December 14, 1983

Federal Express

Mr. William B. Marx
Council of Industrial Boiler Owners
11222 Silverleaf Drive
Fairfax Station, Virginia 22039

Re: Request for Information - New Coal-Fired Boilers

Dear Bill:

In response to your November 20 letter, we have installed a coal-fired boiler since 1977; however, the one boiler is a small industrial steam boiler rated at 20,000 #/hr.

The boiler was installed and placed in operation in 1980 and burns low sulphur western coal having a bag filter for particulate emission control of the exhaust gas.

The impact of establishing 1980 as a baseline for SO_2 and NO_x emissions we believe might not be as severe on our operations as would be the case for larger industrial boiler operations.

If offset requirements are established and impact boilers of this size using low sulphur coal, we may be required to convert from coal to gas/oil firing at an estimated cost of $400,000.

We share the concerns of the Council members in regard to the impact on new installations where coal is currently an economically viable fuel for industrial boiler use. The imposition of a 1980 base cap on new sources of SO_2 and NO_x emissions could result in eliminating coal as a viable fuel source for industrial boilers.

Very truly yours,

Romer G. Wilsek

Romer G. Wilsek

RGW/ma

Dart & Kraft, Inc. 2211 Sanders Road Northbrook, Illinois 60062 (312) 498-8231

#6

E. I. du Pont de Nemours & Co.
Wilmington, North Carolina

Background

E. I. du Pont de Nemours & Company operates a Textile Fibers plant in Wilmington, North Carolina. Prior to 1982, the site burned No. 6 fuel oil for steam generation. At that time, a new two-boiler coal-fired powerhouse was put in operation.

The coal conversion project was economically justified through coal to oil price differentials. PSD permits were obtained for use of equivalent SO_2 emission coal as compared to oil firing. Baghouses were installed for particulate collection, and furnace design for 0.7 lb/MMBtu NOx emission was included. Thus, BACT was applied to the design of this facility.

The Issue

Certain Congressional acid rain bills have been introduced which would cap SO_2 and NOx emissions at 1980 levels. If such a cap were applied to this facility, the new coal boilers would have to switch back to imported oil in order to meet 1980 NOx emission levels. This is due to the inherently higher nitrogen content of coal. Such a restriction on operation would be a severe economic penalty to the facility and the multi-million dollar investment would have been wasted.

JCD/dlt
JCD1:49
12/19/83

BFGOODRICH COMPANY CHEMICAL PLANT - CONVENT, LOUISIANA

#7

Background

The BFGoodrich Company constructed in Convent, Louisiana a chemical manufacturing plant in 1980. An extensive environmental review was conducted on the facility prior to construction by the USEPA, the Louisiana Air Control Commission and the Louisiana Department of Natural Resources. The environmental review on air pollutant emission included an environmental impact assessment, PSD permit review (including Best Available Control Technology (BACT)), Louisiana certificate of approval for air emissions and new source performance standards (NSPS) for an industrial coal fired boiler. Thus, the Convent plant complies with very stringent environmental requirements.

A number of acid rain proposals are being considered now by the Administration and Congress. Most would require emissions reductions by certain sources of sulfur dioxide and nitrogen oxide emissions and would establish a baseline using actual emissions during 1980. Under certain of these proposals, emission increases above this 1980 baseline resulting from expansion of an existing facility or construction of a new facility, must be immediately offset.

The Issue

The BFGoodrich Company started operation of its Convent manufacturing facility in 1981. The facility has a coal fired boiler equipped with Best Available Control Technology for SO_2 and NO_x emissions. A rollback to the 1980 emission levels for SO_2 and NO_x would in effect require zero emissions which is not technically or economically feasible. Further, it is contrary to the purposes of Clean Air Act including, but not limited to Section 109 - National Ambient Air Quality Standards, Section 110 - Implementation Plans, Section 111 - New Source Performance Standards and Part C - Prevention of Significant Deterioration including Sections 160 through 170.

Discussion

The BFGoodrich Company spent considerable time, effort and capital to get environmental approval and construct a modern chemical manufacturing plant, including the only coal fired boiler in the State of Louisiana. The SO_2 and NO_x controls and emisson limits represent Best Available Control Technology. However, the plant did not start operation until 1981. If Congress or the Administration adopts 1980 as the baseline for rollback of SO_2 and NO_x emissions, the BFGoodrich Company would most likely have to cease manufacturing since further reduction of SO_2 and NO_x at this site is not possible.

JWL/kp
4164q

#8

EMISSIONS CAP PROBLEM

INTERNATIONAL PAPER CO. MILL - MANSFIELD, LOUISIANA

BACKGROUND

International Paper Company (IP) constructed in Mansfield, Louisiana, a pulp and paper mill which commenced operation in December 1981. As a new source located in an attainment area for purposes of the Clean Air Act, the Mansfield Mill has to comply with New Source Performance Standards (NSPS) and Prevention of Significant Deterioration (PSD) requirements, including Best Available Control Technology (BACT). Thus, the Mansfield Mill meets strict air emission limitations.

A number of acid rain bills have been introduced during this session of Congress and several options are being studied by the Administration. Most would cap emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x), using actual annual emissions from 1980 as the baseline. Some of the plans would require any facility not operating in 1980 to obtain "simultaneous (immediate) emission offsets" prior to commencing operation; others would exempt new sources meeting NSPS from the emissions cap.

IMPORTANCE TO IP

Unless new sources are exempted from any emissions cap or unless an updated baseline is adopted, clean, efficient mills like Mansfield may not be able to commence or continue operations because SO_2 and NO_x offsets are not available or not affordable.

DISCUSSION

Proposals that require new sources to obtain offsets for SO_2 and NO_x emissions would severely inhibit economic growth in many states and would very possibly prevent IP's Mansfield Mill from continuing to operate. Since it is impossible to obtain zero emissions from scrubbing or fuel switching, offsets would have to be obtained. Because the Mansfield Mill is located in a rural area and in a state with low emission rates, it is not clear that the necessary SO_2 and NO_x offsets are available. Even assuming that a portion of the offsets were available, IP would also be required to install expensive and unproven additional controls (technology beyond BACT) in order to reduce emissions to the required level of offsets.

Penalizing newly constructed, efficient, and clean facilities like Mansfield hardly constitutes wise national policy. Economic growth, especially when controlled by BACT, should not be sacrificed to achieve emission reductions. This is particularly true in the case of the Mansfield Mill which commenced operation in 1981.

CONCLUSION

Requiring SO_2 and NO_x offsets for the Mansfield Mill could prevent operation of the mill, since offsets are probably not available. Therefore, IP urges that new facilities be exempt from the emissions cap.

#9

KENTUCKY AGRICULTURAL ENERGY CORPORATION

Power Alcohol · DDGS · Grain

December 8, 1983

Mr. William B. Marx, President
Council of Industrial Boiler Owners
11222 Silverleaf Drive
Fairfax Station, VA 22039

Dear Mr. Marx:

Thank you for your letter of November 23, 1983. We are very interested in the development of legislation concerning acid rain. Below you will find the answers to your questions. Please advise us if we may be of any further assistance to your effort.

> We have two (2) 60,000 lbs/hr (550 psi) coal-fired, fluidized bed steam boilers. We first commissioned these boilers in December of 1982.
>
> The law in the state of Kentucky limits SO_2 emissions for our boilers to 1.2 pounds of SO_2 per million BTU of coal burned. However, we are operating under a permit with lower SO_2 limits than stated above. We burn 2 to 5% sulfur coal in the presence of limestone. The limestone absorbs the SO_2 as the primary vehicle for SO_2 control. We do no scrubbing of flue gas.
>
> We also have an oil-fired 80,000 lbs/hr backup steam boiler which is normally not in service. There are no SO_2 emission control devices on this boiler.

I am looking forward to further information from you on this effort.

Sincerely,

J. M. Braden
Vice President/Plant Manager

/pl

CC J. N. Wade
G. A. McCarty
File 5.2

Post Office Box 657, Franklin, Kentucky 42134 502-586-9586

Acid Rain Legislation Impact

#16

Background

R. J. Reynolds Tobacco Company is constructing a new manufacturing plant near Winston-Salem, N. C. This facility will occupy a floor space of approximately 1.5 million square feet. Construction began in April 1983 and production will begin in January, 1986. This facility has been designed to meet existing stringent Clean Air Act emission limitations, including the installation of Best Available Control Technology (BACT) required under the Prevention of Significant Deterioration (PSD) program.

Several proposals are being considered by Congress and the Administration concerning action to be taken on acid rain. Most proposals include a cap on emissions of sulfur dioxide and nitrogen oxide, using actual emissions from 1980 as the baseline. Some proposals would require facilities established since 1980 to obtain emission offsets prior to commencing operation.

Issue

If an emissions cap is adopted, this new facility and new efficient plants like it, may not be able to commence operations because SO_2 and NO_x offsets are not available or not affordable.

Discussions

The potential sources for obtaining emission offsets in this area are limited. The problem of establishing offsets is expected to be especially difficult or impossible in areas which have low emission levels. Such low emission levels will be found where the industrial base is small and/or areas where stringent emission limitations have already been met. In this regard the emission cap proposals tend to give the higher emission level areas an economic advantage in that offsets are likely to be more readily available and less costly.

Plans for the facility to begin operation as scheduled would definitely be in jeopardy if offsets are required. An obvious problem would be establishing the necessary offsets by the time of operation. This would be highly unlikely and nearly impossible.

Offsets would still be needed even with the application of additional control beyond BACT. Such technology would be very costly and unproven. The availability and cost of those emission offsets are not clearly defined, creating a great deal of uncertainty as to the eventual cost of this facility, even if the offsets are not required immediately upon start-up.

Conclusion

Facilities like this new plant which have been approved and permitted for construction with the Best Available Control Technology, should not be required to develop offsets under an emission cap approach. Furthermore, the emission cap approach, as generally proposed, would result in a detrimental effect on economic development and industrial growth and create inequitable pollution control costs.

DMR:ss:1659s

COUNCIL OF INDUSTRIAL BOILER OWNERS

PRESIDENT
William B Marx

#11 and 12

Steelcase*

Grand Rapids, Michigan

Boiler went into service - October 1981

Required SO_2 emissions Limit - 1.6# per million BTU

How SO_2 standard is met? - compliance coal

% sulfur in fuel? - 1% sulfur

Kentwood, Michigan

Boiler went into service - November 1983

Required SO_2 emissions limit - 1.6# per million BTU

How SO_2 standard is met? - compliance coal

% sulfur in fuel? - 1% sulfur.

William B. Marx

* Received by telephone from Mr. Gary Egleston of Steelcase

11712 Silverleaf Drive, Fairfax Station, Virginia 22039 • (703) 250-9042

#13

MEMORANDUM

RE: UNION CAMP MILL - EASTOVER, SOUTH CAROLINA

BACKGROUND

Union Camp is constructing in Eastover, South Carolina a (paper and pulp) mill which will commence production in September 1984. Construction began in 1982. As a new source located in an attainment area for purposes of the Clean Air Act, the Eastover mill must meet New Source Performance Standards ("NSPS") and Prevention of Significant Deterioration ("PSD") requirements, including Best Available Control Technology ("BACT"). Thus, the Eastover facility will meet strict air emission limitations.

A number of acid rain bills have been introduced during this session of Congress and several proposals are being studied by the Administration. Most would cap emissions of sulfur dioxide and nitrogen oxide, using actual annual emissions from 1980 as the cap. Some of the plans would require any facility not operating in 1980 to obtain "simultaneous (immediate) emission offsets" prior to commencing operation; others would exempt new sources from the emissions cap.

THE ISSUE

If an emissions cap is adopted, clean, efficient mills like Eastover may not be able to commence operations because SO_2 and NO_x offsets are not available or not affordable.

DISCUSSION

Proposals requiring new sources to obtain offsets for SO_2 and NO_x emissions would severely inhibit economic growth in many states and would very possibly prevent Union Camp's Eastover mill from ever commencing operation. It is not at all clear that the necessary SO_2 and NO_x offsets are available, and offsets are the only alternative under some acid rain plans, since it is impossible to obtain zero emissions from scrubbing or fuel switching. In addition, under some options, the offsets are required to be made prior to commencing operation, thus jeopardizing Union Camp's investment of $600 million in the Eastover facility. Even assuming that Union Camp obtained part of the SO_2 and NO_x offsets needed for Eastover, the Company might also be required to install expensive and unproven additional control technology (beyond BACT) in order to reduce emissions to the required level of offsets. Such actions would be impossible to accomplish within the time frame ("simultaneous") required by some proposals.

Penalizing, or preventing construction of efficient, clean, new facilities like Eastover hardly constitutes wise national policy. Economic growth, especially when accompanied by BACT, should not be sacrificed in order to reduce further future emissions. This is particularly true in the case of the Eastover mill, which began construction many months ago.

(more)

EASTOVER (continued)

CONCLUSION

Requiring SO_2 and NO_x offsets for the new Eastover mill will delay or prevent operation of the plant, since offsets are probably not available. We believe an emissions cap is unwise public policy.

#14

MEMORANDUM

RE: UNION CAMP MILL - PRATTVILLE, ALABAMA

BACKGROUND

Union Camp operates a paper mill in Prattville, near Montgomery, Alabama. In the late 1970's, Union Camp embarked on a major program to expand production capacity at the mill. That expansion project was completed in June 1980 and, therefore, the total annual 1980 sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions include half a year at the lower production/emission rates.

The emissions increases at the Montgomery mill are small compared to the production increase because the mill expansion meets the emission requirements of both New Source Performance Standard ("NSPS") and Prevention of Significant Deterioration ("PSD") regulations. Pursuant to the NSPS and PSD requirements, Best Available Control Technology ("BACT") has been installed at the Prattville mill.

A number of acid rain proposals are being considered now by the Administration and Congress. Most would require emissions reductions by certain sources of sulfur dioxide and nitrogen oxide emissions and would establish a baseline using actual emissions during 1980. Under certain of these proposals, emission increases above this 1980 baseline resulting from expansion of an existing facility or construction of a new facility, must be immediately offset.

THE ISSUE

Union Camp is already using BACT at the Montgomery mill and a rollback to the 1980 emissions levels for SO_2 and NO_x will require switching to expensive fuels and production cutbacks.

DISCUSSION

The Montgomery mill almost doubled its production after June of 1980; therefore, the proposed baseline year 1980 would not accurately reflect the emissions from that facility. If Congress or the Administration adopts 1980 as the baseline for the rollback of SO2 and NO_x emissions, Union Camp will be required to switch fuels to reduce its present SO_2 emissions to 1980 levels. Fuel switching is possible; however, the cost of the new fuels to reduce SO_2 emissions will be approximately $855,000 per year based on 1983 prices.

The NO_x emissions reductions required by some proposals cannot be achieved by changing fuels; nor can Union Camp purchase quickly and install control devices which will effectively remove NO_x from the stack gas emissions. Extensive study and pilot tests would be necessary to determine what emission reductions may be achievable from Union Camp's

(more)

PRATTVILLE (continued)

power boilers. All reductions would have to come from these boilers because there are not known methods to reduce NO_x emissions from the recovery boilers and lime kilns.

In addition, it is virtually impossible for Union Camp to establish a 1980 baseline for NO_x emissions because no data exist. Therefore, assuming a baseline will be established for NO_x, a production cutback is the only certain answer to the NO_x reduction which the acid rain legislation would necessitate, with the concurrent loss of jobs depending on the size of the rollback.

CONCLUSION

We oppose provisions which require offsets of sulfur dioxide and nitrogen oxide emissions for new sources and the expansion of existing sources where NSPS and BACT requirements are being met. We believe such rollback requirements run counter to the important national goal of encouraging new, clean, and efficient industrial facilities.

IMPACT OF EMISSIONS CAP PROPOSAL ON WEYERHAEUSER'S COLUMBUS, MS FACILITY

Weyerhaeuser currently operates a thermomechanical (TM) pulp mill and lightweight coated paper manufacturing facility at Columbus, MS. The plant began operation as a new "greenfield" project just over one year ago, and represents a major investment for the company. The plant employs about 380 people.

The company has plans to expand our Columbus operations by adding three additional plants (a kraft pulp mill, a paper mill, and another TM mill with coated paper manufacturing). Bringing these additional plants on line would raise total employment to the 800 to 850 range.

Weyerhaeuser obtained a PSD (prevention of significant deterioration) permit for the full four-plant complex that would allow SO_2 and NO_x emissions as follows:

SO_2	13,316 tons/year
NO_x	6,556 tons/year

However, the facility is not emitting at these levels because the three additional facilities have not yet been built and because we are primarily using low-emissions hog fuel (wood waste material) instead of coal or oil. Estimated current actual emissions are only a fraction of allowable emissions:

SO_2	200 tons/year (1-1/2 percent of allowable emissions)
NO_x	500 tons/year (8 percent of allowable emissions)

If a legal requirement were imposed limiting Columbus to current actual emissions, expansion to the three additional plants would require the installation of scrubbers achieving more than 98 percent reduction of SO_2 emissions, advanced NO_x reduction techniques and/or reductions from other facilities as offsets. The required SO_2 and NO_x control technologies would exceed available state-of-the-art efficiencies and would be very expensive. Sufficient offsets would probably not be available, as Columbus is not near many other large emitting sources.

For these reasons, an emissions cap would be a significant factor in any decision by the company to proceed with the planned expansion (or any other expansion), and could independently result in a decision not to expand the facility. Moreover, if expansion is prevented, our existing large investment could be jeopardized since the economic viability of this plant was based on an analysis that assumed construction of the entire four-plant complex.

s125/1125/e2
11/11/83

cibo
COUNCIL OF INDUSTRIAL BOILER OWNERS

ISSUE PAPER

Guidelines for Public Acid Deposition Control Measures

INTRODUCTION

Recent studies, notably the National Academy's "Acid Deposition: Atmospheric Processes in Eastern North America", make it clear that today it is not possible to identify the specific change in the acid deposition patterns that would result from a given change in precursor emissions, nor to determine the relative importance of local sources and long-range transport. As a consequence, CIBO states its belief that these uncertainties make it very difficult for Congress to legislate equitable and cost-effective solutions to this problem at present. For the future, however, legislative concepts could be developed embodying the following principles:

GUIDELINES

A. Achieve The Most Equitable Cost-Effective Solution(s) In The Shortest Time

- *COST-EFFECTIVENESS*
  The utility industry is alone in its ability to effect a true cost-effective result because of large unit size and economy of scale. Because the average utility boiler is about 35 times as large as the average industrial boiler, control systems applied to a utility unit will remove a ton of SO_2 at a cost of $400, compared to $1400 for an equivalent removal from a typical industrial boiler, thus costing the public far less for the same benefit.

- *AIR QUALITY IMPACT*
  In 1981 industrial boilers consumed only 57 million tons of coal as compared to the utilities' 596 million. By 1995 industrial coal use is widely predicted to increase by about 40 million tons annually, resulting in an additional SO_2 emissions inventory of less than 500 thousand tons. Underscoring this modest impact is a recent State of Pennsylvania study showing that even with maximum feasible increased industrial coal use, the added SO_2 air quality impact would be only 1.2% in that state.

- *EQUITABLE BURDEN*
  Industry will pay twice unless legislation is confined to utility sources—through direct compliance costs *and* increased electricity rates. Electricity used by industry in 1981 totalled 2.85 quads of electrical energy at a cost of $37 billion. At a forecasted average industrial rate increase of anywhere from 15-65%, industry automatically will pay its share of added utility control costs. To impose direct control costs would be inequitable and bad for the economy.

- *CONTROL STRATEGY*
  Control strategies should be limited to SO_2 emissions until the various NOx control technologies are commercially demonstrated.

11222 Silverleaf Drive • Fairfax Station, Virginia 22039 • 703/250-9042

B. Insure That National Energy and Economic Goals Are Not Adversely Affected

- *Legislation which specifically mandates control measures based on uncertain scientific analysis inhibits the making of sound economic decisions by business with the following deleterious economic, energy and environmental effects:*
  1. Hamper expansion, limit efforts to increase productivity and reduce industrial competitiveness;
  2. Dampen industry's move back onto coal;
  3. Retard the development of emerging SO_2 and NOx control technologies for industrial applications.
- *The imposition of an emissions cap will be particularly harmful in that it would:*
  1. Bar increased industrial coal use. A cap, especially on NOx emissions; with relative gas, oil and coal emission rates of 2:3:7, respectively; would make expanded coal use impossible.
  2. Severely limit industrial fuel flexibility, restricting a plant's capacity to manage fuel supply interruptions, with potential damaging effects to production, employment and national defense.
  3. Impose a second layer of control on new sources, already required to meet NSPS or BACT standards.
  4. Set an artificial limit on plant production.
  5. Ironically, a cap based on some past emissions rate, i.e. a "roll back", would impact most adversely those very plants which have aided achievement of an important national energy goal through recent increased coal use.

C. Employ A Phased Program

- *Evaluation of the results of emissions reductions from a concentrated area on an ecologically sensitive target impact site to determine further reduction needs.*

D. Accelerate Research Efforts In The Following Fields

- *Integration of results from private sector emission control technology programs already underway.*
- *Analysis of NOx emissions and their relative contribution.*
- *Development, demonstration and evaluation of SO_2 and NOx control technologies.*
- *Assessment of the relative cost-effectiveness of various SO_2 and NOx technologies.*

CONCLUSION

CIBO looks forward to a continuing working relationship with government, especially to monitor, evaluate and report developments in:

A. **Industrial boiler fuel use;**
B. **Industrial boiler air quality impacts;**
C. **Emerging technologies in SO_2 and NOx control suitable for industrial boiler application.**

We believe that this role will help to identify equitable and cost-effective acid deposition control measures.

ELECTRICITY
CONSUMERS
RESOURCE
COUNCIL

1828 L Street, N.W., Suite 403
Washington, D.C. 20036
202-466-4686

Jay B. Kennedy
Executive Director

April 26, 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
APR 27 1984

Senator James A. McClure, Chairman
Committee on Energy and Natural Resources
United States Senate
361 Senate Dirksen Office Building
Washington, D.C. 20510

Dear Senator McClure:

In response to your letter of April 16, 1984, please find enclosed 30 copies of ELCON's statement on proposed acid rain legislation.

We at ELCON have no particular expertise in the environmental sciences. However, we have studied the acid rain issue at some length to determine its likely impact on electric utilities and ultimately on the cost of electricity paid by our member companies. The enclosed statement represents our views on proposed acid rain legislation from the perspective of electricity consumers who ultimately will bear the cost of an emissions reduction program.

We appreciate the opportunity to comment on this important issue.

Yours truly,

Jay B. Kennedy

Jay B. Kennedy
Executive Director

JBK:pja

Enclosure

Dr. Jay B. Kennedy

ELCON

STATEMENT OF THE
ELECTRICITY CONSUMERS RESOURCE COUNCIL

TO THE
UNITED STATES SENATE
COMMITTEE ON ENERGY AND NATURAL RESOURCES

ON
PROPOSED ACID RAIN LEGISLATION

APRIL 26, 1984

Electricity Consumers Resource Council (ELCON)
1828 L Street, N.W., Suite 403
Washington, D.C. 20036
(202) 466-4686

The Electricity Consumers Resource Council (ELCON) is pleased to submit the following statement to the Subcommittee on Energy and Natural Resources of the United States House of Representatives. The purpose of this statement is to present ELCON's views on current legislative proposals to impose an emissions reduction program on the nation's electric utilities.

ELCON is an association of large industrial consumers of electricity with facilities in most of the fifty states.[1] ELCON's members consume approximately 10 percent of all electricity sold to industrial consumers and nearly 5 percent of all electricity sold in the U.S.

Because of our members' need for electricity, ELCON has a significant and continuing interest in the electric utility industry. ELCON advocates and promotes the development and adoption of coordinated, rational and consistent federal, state and local policies which will assure an adequate, reliable and efficient electricity supply for all users at prices based on the costs incurred in providing service. Due to the impact of any acid rain legislation on the cost and reliability of electric service, ELCON has a significant interest in the proposed legislation. We appreciate the opportunity to comment on this important issue.

---

[1] This statement is presented on behalf of the following ELCON members: Air Products and Chemicals, Inc.; Airco Industrial Gases; Anheuser-Busch Companies, Inc.; Armco Inc.; Bethlehem Steel Corporation; Diamond Shamrock Corporation; Dow Chemical U.S.A.; E.I. du Pont de Nemours & Company; General Motors Corporation; Hercules Incorporated; Kaiser Aluminum & Chemical Corporation; LCP Chemicals & Plastics, Inc.; Olin Corporation; PPG Industries, Inc.; Stauffer Chemical Company; and Union Carbide Corporation.

SUMMARY OF POSITION:

Industrial consumers of electricity are concerned about the environment, and we expect to pay our fair share of any necessary acid rain program. We are forced, however, to deal with the facts of the marketplace. During these times of increasing competition in world and domestic markets, we must be certain that any additional cost imposed on the United States is justified by an offsetting benefit.

Industrial consumers of electricity are also concerned that the debate over acid rain will degenerate into an argument over whose estimate of the cost impact of an emissions reduction program is the most accurate. This argument ignores the benefit side of the equation.

ELCON has studied the acid rain issue at some length and has reviewed the statement of EPA Administrator Ruckelshaus presented before the Senate Committee on Environment and Public Works on February 2, 1984. We support the position of the Reagan Administration which calls for increased and accelerated research of the acid rain phenomenon and increased research and development for improved control technology.

EMISSIONS REDUCTION PROGRAMS ARE EXPENSIVE:

Estimates of the cost of an emissions reduction program vary significantly and are based on a number of uncertain assumptions, including: the capital cost of retrofitted scrubbers; the fuel and operating and maintenance (O&M) expense associated with this technology; the availability of new, less costly technology; the price differential and availability of low-sulfur versus high-sulfur coal; interstate and intrastate trading of emissions reductions; protection of local coal sources; and coal transportation costs. In addition, the capital cost and fuel and O&M expense associated with current scrubber technology are highly site specific. Actual costs may vary substantially from estimates once an emissions reduction program is underway. Also, different legislative proposals have different regional impacts depending upon the specific language and implementation programs incorporated in the bill.

ELCON has analyzed a number of studies that provide cost estimates of emissions reduction programs. Some of these are associated with particular legislative proposals, others estimate the cost of specific levels of emissions reduction.[2] ELCON cannot vouch for any particular one of these estimates, since they are based on a number of uncertain and often unspecified assumptions. The important point is that all of these estimates are quite large, ranging from $1.8 billion to $24.9 billion in total cumulative capital costs and $3.3 billion to $7.9 billion in total annual costs.[3]

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[2] These studies are: Edison Electric Institute, "A Report on the Results from the Edison Electric Institute Study of the Impacts of the Senate Committee on Environment and Public Works Bill on Acid Rain Legislation (S. 768)," by National Economic Research Associates, Inc., June 20, 1983; Edison Electric Institute, "Evaluation of H.R. 3400, The Sikorski/Waxman Bill for Acid Rain Abatement," by Temple, Barker and Sloane, Inc., September 20, 1983; Energy Information Administration, U.S. Department of Energy, Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries, June 1983; ICF, Inc., "Analysis of Coal Production and Employment Impacts of the Waxman-Sikorski Bill and a Cost-Effective Equivalent," for the Alliance for Clean Energy, September 22, 1983; ICF, Inc., "Potential Impacts of Alternative Acid Rain Initiatives on Electric Utility Rates in the U.S.," for the Aluminum Association and ELCON, August 18, 1983; ICF, Inc., Analysis of a Senate Emission Reduction Bill (S. 3041), Environmental Protection Agency, February 1983.

The cost of the emissions reduction programs currently proposed can have a significant impact on electricity prices, on the costs of industrial firms and ultimately on consumer prices. An analysis sponsored by ELCON and the Aluminum Association estimates that state average industrial electric rates could increase as much as 20 percent and residential rates by more than 13 percent due to an emissions reduction program.[4] Actual cost impacts on individual utility systems within a state would vary considerably, depending upon the circumstances of the particular utility.

Some utilities predict rate increases of 30 percent to 50 percent, while others expect very small rate increases or none at all. In addition to capital cost increases, utilities would experience increased fuel and O&M expenses due to proposed acid rain legislation. These costs could be two or three or more times as much as associated capital costs on an annual basis.

A NET REDUCTION IN EMISSIONS MAY NOT BE ACHIEVED:

Analyses of proposed emissions reduction programs indicate that emissions levels will likely reach the same point at a future date regardless of the implementation of acid rain legislation. For example, a study performed for the U.S. Department of Energy states that emissions from coal-fired generating plants will decline continually as old units are retired.[5] When new plants with more advanced pollution control technology take the place of old ones, the study estimates that emission levels will be approximately the same with or without acid rain legislation. A similar analysis performed by the Electric Power Research Institute (EPRI) indicates that acid rain legislation would reduce emissions below otherwise achievable levels for a period of about twenty years (1985 to 2005).[6] After this period the study shows that emissions will be about the same with or without the legislation.

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[3] These estimates are for a 10 million ton reduction in emissions below 1980 levels for the 31 eastern states.

[4] ICF, Inc., "Potential Impacts of Alternative Acid Rain Initiatives on Electric Utility Rates in the U.S.," op. cit.

BENEFITS ARE UNCERTAIN:

We need to consider if reducing emissions early, but to the same level as would be attained without the program, is worth the program cost. That is, will the reduction in emissions result in a significant reduction in acid deposition and will that reduction produce benefits sufficient in dollar amount to justify the expenditure of billions of dollars? Our understanding is that based on present scientific knowledge, this question cannot be answered with any appreciable degree of accuracy.

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[5] Energy Information Administration, U.S. Department of Energy, Impacts of the Proposed Clean Air Act Amendments of 1982 on the Coal and Electric Utility Industries, June 1983.

[6] Electric Power Research Institute, "Developing the Options for Emissions Control," in EPRI Journal, Vol. 8, No. 9, November 1983.

The Congress must make hard economic decisions based on verifiable evidence with predictable results. Consumers cannot afford to spend billions of dollars annually on a program that has only uncertain and unquantified benefits. Decisions involving such a large commitment of our nation's resources should be based on the assurance that a favorable benefit-cost relationship will result. Since the environment is such an important national priority, decisions of this magnitude affecting the environment are important enough to be based on sound scientific evidence, not vague assertions of future benefits.

THE DEBATE IS INCOMPLETE:

Several issues have been neglected in the many discussions of acid rain impact. There is a serious question as to the impact acid rain legislation might have on the demand for and price of domestic and imported oil. Certainly, utilities would be encouraged to continue burning oil when they have the capacity to do so rather than spend huge sums on new coal units or plant modifications. This fact combined with a lack of enthusiasm for nuclear units might jeopardize the reliability of the electricity supply system in the near future.

You have heard substantial comment by ELCON and others as to the dollar cost of an emissions control program. The important issue is the real cost to the U.S. and its standard of living if tens of billions of dollars worth of resources are used to control acid rain with no assurance of an equivalent real benefit. Those resources have alternative uses in the private and public sector for schools, medical care, roads, etc. If used to control acid rain, then by definition they are not available for other real income purposes. It is this cost that is important.

CONCLUSION:

ELCON is concerned about the impact that proposed acid rain legislation would have on U.S. industry and the U.S. generally. Therefore, we believe that Congress must seriously consider the effectiveness of any proposed legislation in achieving its goals and the cost burden associated with that legislation. We are concerned about the environment but we are also concerned that any program implemented produce sufficient benefits.

TENNESSEE VALLEY AUTHORITY
KNOXVILLE, TENNESSEE 37902

OFFICE OF THE BOARD OF DIRECTORS

May 8, 1984

The Honorable James A. McClure, Chairman
Committee on Energy and Natural Resources
United States Senate
Washington, D.C. 20510

Dear Mr. Chairman:

Enclosed are several items which we request that you include in the record of the acid rain research hearing that your Committee held on April 30: (1) three sections of the testimony the Tennessee Valley Authority (TVA) presented at a hearing of the Senate Environment Committee on Environment and Public Works, (2) a detailed statement explaining TVA's experience with developing an atmospheric fluidized bed boiler and our plans for a demonstration facility using this technology, and (3) a TVA assessment of the status of acid deposition research.

We hope these items add to the hearing record. We will be happy to answer any questions they raise.

Sincerely,

C. H. Dean, Jr.
Chairman

SK:CMH
Enclosures

STATEMENT OF MICHAEL D. HIGH
DIRECTOR
DIVISION OF ENERGY DEMONSTRATIONS AND TECHNOLOGY
TENNESSEE VALLEY AUTHORITY
BEFORE THE
SUBCOMMITTEE ON ENERGY DEVELOPMENT AND APPLICATIONS
COMMITTEE ON SCIENCE AND TECHNOLOGY
UNITED STATES HOUSE OF REPRESENTATIVES
MARCH 6, 1984

Mr. Chairman, I am Michael D. High, Director of the Division of Energy Demonstrations and Technology of the Tennessee Valley Authority (TVA). I appreciate the opportunity to address this committee on TVA's experience with the atmospheric fluidized bed combustion (AFBC) of coal and TVA's plans for a demonstration facility using this technology.

AFBC is an advanced coal-burning process, which provides a method of burning coal economically and in an environmentally acceptable manner. TVA sees this technology as a near-term alternative to conventional coal-fired steam plants, which require complex environmental control technologies in order to meet emission control standards. AFBC appears to offer the utility industry a near-term solution for direct burning of a variety of abundant and less costly coals, lower costs for generating electricity, and the ability to meet and exceed present environmental requirements.

Inherent to the AFBC process are a number of desirable features: Sulfur dioxide, an undesirable by-product of burning coal, is captured by calcium oxide formed from the limestone in the bed, thus removing the need for a scrubber to produce calcium sulfate (gypsum plaster when hydrated).

Comprehensive Department of Energy studies indicate that this dry, by-product may have useful applications or, at the least, provide a material which can be conveniently disposed of in an environmentall acceptable manner. In addition, since the operating temperature of fluidized bed is around 1,550°F, the formation of nitrogen oxides i significantly reduced. Conversely, a conventional plant operates a roughly twice the temperature, which results in higher nitrogen oxi

Equally as important as the environmental control capabilities are advantages offered by the AFBC process. The highly efficient heat characteristics of boiler tubes within the fluidized bed reduce the physical size of the heat transfer surface in the boiler. The need flue-gas scrubbing equipment is eliminated, and particulate capture commercially available baghouses is enhanced. These attributes res capital costs for AFBC plants, which are estimated to be less than for a new conventional plant equipped with flue-gas scrubbers and electrostatic precipitators, once beyond the first-of-a-kind stage. Without the additional scrubber equipment and personnel required to the scrubber and with lower cost high-sulfur coal, operating and maintenance costs are also projected to be lower.

In September 1976, TVA's Board of Directors approved phase I of a project leading to the design and construction of a utility AFBC po plant. Contracts were awarded to three major boiler manufacturers

(Babcock & Wilcox, Combustion Engineering, and Foster Wheeler) to c preliminary designs and cost estimates for a 200-MW(e) demonstratic boiler and an 800-MW(e) commercial AFBC boiler and auxiliary equipm parallel with these contracts, TVA internally carried out prelimina designs and cost estimates for the plant site, coal and limestone h facilities, power plant building, turbine/generator, and other "bal plant" facilities. Using these cost estimates as a basis, an econc analysis was performed considering a "retrofit" boiler, a "standalc unit at an existing site, and a new plant at a new site. Cost comp to a conventional pulverized-coal plant with wet limestone scrubber indicated that an AFBC plant produces electricity at a cost which i approximately 10 to 15 percent lower than that of a conventional pl scrubbers. In addition, studies were initiated for the selection c suitable site somewhere in the Tennessee Valley region on which to 200-MW(e) demonstration facility. At an early date, it was recogni a pilot plant, which could be operated under utility conditions, wa in order to provide the design data, performance results, and equip evaluations needed to design a demonstration plant. A conceptual d for a pilot plant was also completed. Since these initial studies, AFBC activities have evolved into three major project areas: (a) a 20-MW(e) AFBC pilot plant, (b) a 160-MW(e) AFBC demonstration plant (c) supporting research and development.

20-MW(e) AFBC Pilot Plant

Several small-scale AFBC development units built and operated by others continue to confirm the attractiveness of this technology, but none answer the many engineering design and operating questions which must be resolved before this technology can be used in a commercial-sized utility plant. Neither do they permit assessment of the full environmental impact of this technology. Consequently, to provide design confidence and the flexibilit to test process improvements along with emission controls, TVA purchased a 20-MW(e) AFBC pilot plant in September 1979. The pilot plant is built on the TVA Shawnee Steam Plant site in Paducah, Kentucky. The total facility cost through construction was $68.4 million. This utility-oriented pilot plant provides TVA with the means to show that efficient an cost-effective performance of an AFBC boiler and related auxiliary systems can be obtained under utility operating conditions. These conditions demand more fluctuating steam rates and higher steam conditions than the planned industrial boilers and the existing bench-scale AFBC units. Site work was started in April 1980 and operational testing commenced in the summer of 1982. A cosponsored $28.5 million contract with the Electric Power Research Institute (EPRI) for operational testing of the pilot plant was signed in June 1980. Through December 1983, there has been $36.4 million in congressional appropriations, $38 million in power funds, and $7.4 million in EPRI funds expended on this project.

The pilot plant is considered essential for the engineering development of the crucial AFBC process control scheme. This control scheme must delicately balance steam production and the inherent AFBC capacity to limit pollutants over a wide range of changes in load demand during any 24-hour period. The pilot plant is equipped with the most sophisticated computerized control systems available to enhance our engineering knowledge of the complex relationships of all operating variables that influence steam production and environmental control. The pilot plant is also necessary to develop, test, evaluate, and compare large-scale auxiliary components and variations in AFBC boiler configurations to facilitate optimum selection of components for a utility-scale AFBC boiler.

The pilot plant is equipped with several alternate process and equipment configurations. These systems are being used to develop a data base for the 160-MW(e) AFBC Demonstration Plant. Additionally, an excellent opportunity exists to eventually use this pilot plant test facility to establish a data base to compare a wide range of fossil fuel grades, such as lignites, coal-cleaning plant "rejects," and other lower grade fuels, enable the design scaleup and use of these fuels in an AFBC utility boile This fuel diversification potential could markedly improve the Nation's chances of achieving energy independence.

The 20-MW(e) AFBC Pilot Plant is complete and fully operational. Since the first coal fire in May 1982, the unit has accomplished over 5,000 hours of testing with high-sulfur Kentucky coal. The AFBC boiler has operated exceptionally well, and there have been no significant AFBC technology-related problems, such as erosion of the tubes in the fluidized bed. Process performance has also been encouraging. The AFBC process can achieve in excess of 90-percent sulfur removal with a 4.2-percent-sulfur coal. It can also achieve a combustion efficiency of greater than 97 percent within an economical viable range of operating parameters. Additionally, the nitrous oxide emissions are substantially lower than the New Source Performance Standards and fall consistently in the ranges referenced for low nitrous oxide burner performance.

160-MW(e) AFBC Demonstration Plant Project

In September 1979, preliminary designs leading to preliminary cost estimates for a 200-MW(e) AFBC demonstration plant were initiated by contracts with Babcock & Wilcox, Combustion Engineering, and Babcock Contractors, Incorporated. For each of the designs, TVA performed plant layouts and balance-of-plant designs and prepared a preliminary draft Environmental Impact Statement (EIS). The preliminary designs were refinements of the earlier conceptual designs. Combustion Engineering, in conjunction with Lurgi-Chemie, also prepared a conceptual design of a 200-MW(e) circulating fluidized bed combustion demonstration plant. The work of the three boiler manufacturers was completed in January 1981. TVA's evaluations of these designs, plant cost estimates, schedule, and a preliminary boiler specification were also completed in 1981.

In late 1980, TVA considered the possibility of pursuing retrofit or add-on options because of load forecasts, funding availability, and regulatory requirements rather than building a standalone plant for the demonstration project. A retrofit configuration involves dismantling an existing boiler and replacing it with a new boiler in the same powerhouse; whereas, an add-on consists of a new boiler and boiler building built adjacent to the existing one. A standalone plant offers greater flexibility, but it has since been shown that the add-on option offers the greatest benefit-to-cost ratio. TVA has prepared a preliminary cost estimate (±30 percent accuracy) and conceptual design for 160-MW(e) retrofit and add-on units at Shawnee unit 10.

TVA has also performed brief studies and cost analyses wherein tailings from coal-washing facilities were used as a "free" fuel for AFBC steam generators. As a result of these studies, it had been determined that a boiler designed for firing coal-wash tailings would not likely be cost effective in an AFBC plant for the TVA system. Since there are also no significant technical advantages for using coal-wash tailings in an AFBC demonstration, TVA has no reason to build such a plant, because the additional power is not needed.

Based upon these studies, it was determined that the add-on approach could adequately demonstrate the technology in a cost-effective manner. Presently, TVA, Duke Power Company, the Commonwealth of Kentucky, and EPRI (the Principals) are working on a preliminary design and ±10 percent cost estimate for a 160-MW(e) add-on unit at Shawnee unit 10.

Also based on these studies, TVA has concluded that the next major step, a utility-scale demonstration facility, can be accomplished by replacing an existing pulverized-coal-fired boiler with an AFBC boiler. This approach will accomplish the goals of demonstrating the essential elements of the technology at a significantly lower cost than a new standalone facility.

To demonstrate the technology, an AFBC boiler would be constructed beside an existing unit at the plant as a replacement for the existing boiler. The AFBC boiler would be capable of generating approximately 160 MW(e) of electric power and would make maximum use of the existing turbogenerator set and other associated equipment. The design fuel for the demonstration is high-sulfur Illinois basin coal, as typified by Kentucky number 9. However, fuel flexibility will be considered with testing of alternate fuels during the test program. The preliminary cost estimate for the design, construction, and startup of the AFBC demonstration at Shawnee is $200 million. It is anticipated that a 3- to 4-year test and demonstration period would cost approximately $20 million.

The schedule as presently proposed allows an adequate amount of time to evaluate the pilot plant test results prior to freezing boiler designs. On this schedule, detailed design and erection of the facility will begin in 1984 and will be completed by mid-1989. Operational testing, producing power for TVA's grid, would begin in 1989. This timetable provides the electric power industry with the option of selecting an AFBC coal-fired plant in the early 1990s to provide added or replacement power to their grid in the mid-to-late-1990s.

A total of $30 million in deferred appropriations ($15 million in FY 1985 and $15 million in FY 1986) for TVA through the Department of Energy for Federal participation in the TVA 160-MW AFBC Demonstration Plant has been approved by the U.S. Congress. These funds are for the construction of the facility.

The Principals have committed a total of $135 million to the 160-MW(e) AFBC Demonstration Plant project. Kentucky has committed $10 million from their demonstration trust fund, Duke Power has committed $10 million, EPRI has committed $75 million, and TVA has committed $40 million. TVA's contribution will come from its self-financed power system, rather than from appropriations. In addition to this $40 million, TVA is providing a site, turbogenerator, baghouse, chimney, and coal-handling equipment, as well as other equipment. Also, $7.9 million has been spent on previous AFBC Demonstration Plant activities, which will be of benefit to this project. Of this amount, TVA has contributed $6.9 million in power funds, and DOE has contributed $1 million.

Remaining funds are now being sought from other utilities, foreign countries, State governments, coal companies, railroads, boiler manufacturers, and others. We have received indications of the intent to join in financial participation in excess of $25 million from a number of these sources and expect to get the remaining required funds in the near future.

Supporting Research and Development

TVA, EPRI, the boiler manufacturers, and others have identified a number of technical areas that are critical to the development of AFBC technology. Major areas identified are coal feeding, boiler construction materials, boiler control recycling of fly ash, and handling and disposing of by-products. To address these areas, TVA has undertaken a substantial number of research and development projects over the last several years. In fact, TVA has undertaken more than 50 research and development assessments and support tasks at a cost of more than $7.6 million. Of this amount, TVA provided $7.0 million in power funds and $0.6 million in appropriated funds. TVA was responsible for conducting the work or technically monitoring the work of contractors for the following programs:

- TVA designed, built, and operated a coal-feed test facility at the Watts Bar Steam Plant to evaluate the effectiveness of the Fuller-Kinyon feed pump and 3:1 and 24:1 feed-line splitters as well as to evaluate the effects of coal/limestone surface moisture.

- The Oak Ridge National Laboratory (ORNL) performed many experiments and studies in fluidization, material corrosion, coal/limestone feeding and conveying, fluidized combustion, and modeling.

- TVA, the National Coal Board, and EPRI participated in coal/limestone burn tests and boiler tube material evaluations at Leatherhead, England.

- General Atomic performed recycle tests.

- The University of Tennessee performed tests of coal-feed nozzles, air distributor plates, and alternate feed concepts and performed studies of boiling heat transfer and 2-phase fluid flow in tube bends.

- TVA and Jaycor jointly prepared a transient mathematical model of the pilot plant.

- ORNL and TVA jointly prepared a steady-state process model for the AFBC process.

- The Massachusetts Institute of Technology performed various fundamental fluidized bed combustion studies and tests.

- Several other tests were conducted at facilities, such as Battelle Memorial Institute, FluiDyne, Kentucky Institute for Mining and Minerals Research, and others.

- TVA obtained numerous environmental permits, licenses, and clearances in support of the pilot plant. In addition, a draft EIS, which incorporated draft Prevention of Significant Deterioration and National Pollutant Discharge Elimination System Permit applications, was prepared.

TVA has been interested in fluidized bed combustion technology since 1975 and consequently has developed a broad base of experience. A total of 445 man-years of experience is culminated in 125 design engineering, development engineering, operations, and technical management personnel. Many training courses, seminars, and conferences have been attended by people assigned to AFBC projects.

From TVA's viewpoint, AFBC is an important and viable technology which can significantly benefit the Nation, and it deserves continued Federal support to ensure that its goals are achieved. I appreciate the opportunity to present our program and views. I would be pleased to answer any questions this committee has. Thank you.

EXCERPTS FROM THE
STATEMENT OF
BOARD OF DIRECTORS
TENNESSEE VALLEY AUTHORITY
BEFORE THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS
UNITED STATES SENATE
FEBRUARY 9, 1984

TVA Position

The TVA position on acid rain is not consistent with the views of the Administration on this issue, and represents the opinion of the TVA Board. Simply put, our position on acid rain is that a reduction in acid precursors is essential in eastern North America, and that Federal legislation is necessary to accomplish this. Reductions should be required of all significant emitters of SO_2, both utilities and other industries. These SO_2 reductions should be allocated to the States proportionally to their total SO_2 emissions for the 1980 base year. States should have flexibility in allocating their required emissions reductions.

TVA believes in the principle that the polluter should pay, and we practice what we preach. The costs of further reduction should be borne by the polluters and thus passed on to consumers. Maximum flexibility should be given to emitters to select the most cost-effective way to reduce their emissions. If acid rain legislation is structured in this way, we estimate the increased cost to TVA ratepayers could be about 4-6 percent for our share of a 12-million ton national reduction. We stand willing to do our fair share in any cleanup effort.

The majority of the TVA Board supports legislation now to achieve a 10-12 million-ton reduction in SO_2 over the next decade in a cost-effective manner and without subsidies of any kind, but the Chairman prefers to wait until EPA recommends a level of national SO_2 emissions with the understanding that TVA would meet its fair share of the reductions at that time.

Acid Rain Research

Acid rain is too often thought of as a regional problem, confined to the northeastern United States and eastern Canada. However, we have rainfall in the Tennessee Valley which is as acidic as that found anywhere in North America. Based on a monitoring program which began in 1971, we know that on an average annual basis our rainfall is in the pH 4.1 to 4.4 range--typical of the values for New England, and we get much more rainfall than New England. The pH of rainfall at monitoring sites remote from our fossil-fired generating plants is similar to that which falls at monitoring stations at the plants themselves. While our data do not show any trend toward increased acidity, comparative data for the eastern United States between 1955 and 1973 do indicate a trend toward decreased levels of pH and increases in the aerial extent of low pH rainwater. These data are of particular concern to us because most of the increase seems to be toward the Southeast.

While we have no direct evidence of a link between acid deposition and impacts to resources in our region, several observations over the last several years could be related to acid deposition. We have found, for example, that after rainfalls the pH levels of some streams are depressed to the extent that aquatic life could be adversely affected. Our initial research indicates that in one particular watershed the acidic nature of the soils appears to be the probable cause of the pH depression. We have also observed fishkills at trout rearing facilities, unusually high incidences of skeletal deformities in smallmouth bass in several reservoirs, and a decline in the range of the native Appalachian brook trout over the last two decades. These observations could be linked to acid rain, although pesticide and herbicide runoff and natural soil acidity are also possible causes for some.

Some possible terrestrial effects also have been observed. We have recently become aware of a problem with increased mortality and decreased vigor of trees in the Valley region that began about 20 years ago. Core samples show a buildup of heavy metals in the trees associated with this condition. The cause of this widespread problem has not been determined. There are scientists, both within TVA and outside, who believe that acid deposition could be a causative factor.

Technology Research

TVA has done pioneering work in SO_2 emissions control technology since the late 1960s, and our major role in flue gas desulfurization development began in 1972 with the construction of three 10-MW pilot plants at our Shawnee Steam Plant in Paducah, Kentucky. Since then, more than $35 million has been invested by the Environmental Protection Agency, Electric Power Research Institute, the Department of Energy, TVA, and others at this facility. Numerous technology advancements are available today because of this effort. For example, developments in forced oxidation and waste disposal will enable us to retrofit these technologies into the full-scale scrubbers at our Widows Creek units 7 and 8. We are also active in preparing technology assessments and cost estimates for both recovery and throwaway processes. These estimates are quoted throughout the industry.

Today, our efforts are also focused on demonstrating Atmospheric Fluidized Bed Combustion (AFBC) which we think holds the greatest promise for the future of high-sulfur coal. TVA projections indicate that a new

AFBC boiler fueled with Illinois-basin, high-sulfur coal will produce electricity at a cost 10 to 20 percent less than a conventional plant with scrubber. Such a plant could achieve greater than 90 percent sulfur removal and would produce less oxides of nitrogen than a conventional plant. This projection is based on our experience with the AFBC 20-MW test facility which we have operated for almost two years.

TVA has taken the lead in a cooperative development with the Electric Power Research Institute, Duke Power, the State of Kentucky, and others in designing and demonstrating a commercial-size plant. Of the $220 million required $30 million is being provided by the Federal treasury. We are now designing the plant and if all goes well, this technology should be commercially available in the 1990s.

TVA is also actively pursuing dry flue gas desulfurization technology (commonly known as spray dryer) on high sulfur coal at the Shawnee Steam Plant. Two pilot plants supplied by different vendors are providing critical data necessary to adopt this technology in the eastern United States. We are considering a larger, commercial scale demonstration of this technology.

Other technologies that need further development or demonstration include double alkali using limestone, limestone injection multiple burner; lower cost recovery systems, retrofittable technologies for existing outdated limestone scrubbers, and combined NO_x/SO_2 removal processes.

TVA is also involved in research to improve our technology for removing sulfur from coal. For example, we are demonstrating at our Paradise Steam Plant high gradient magnetic separation technology which improves Btu recovery and sulfur reduction in the fine coal washing circuit. We are conducting research on oil agglomeration and magnetite recovery processes which recover clean coal from fine coal refuse and extract magnetite from fly ash, respectively.

Additional research is needed to develop some cost-effective chemical coal cleaning technology that may be tailored to remove almost any desired amount of sulfur from coal, especially for those cases where greater than 50- to 60-percent reduction in sulfur is required. Research and development of this type, along with various synthetic fuel processes, provide hope for the future of the high-sulfur coal industry.

ASSESSMENT OF ENVIRONMENTAL EFFECTS OF ACIDIC DEPOSITION

Executive Summary

Many scientists, including those of the Tennessee Valley Authority, now recognize as a working hypothesis that acidic deposition can contribute to long-term damage to sensitive ecosystems. It is evident that scientifically assessing acidic deposition impacts is much more complex than it first appeared, and establishing unique cause-and-effect relationships may not be possible. It is extremely difficult to isolate the effects of acidic deposition from those of other factors. However, from the perspective of a TVA assessment of presently available knowledge, acidic deposition is likely one factor but not the only factor involved in effects on forests, waters, and fish. There is little direct evidence of environmental impact of acidic deposition, and TVA has no direct evidence of a link between acidic deposition and impacts on the resources in the Tennessee Valley. In spite of this lack of direct evidence, the probability of cumulative impacts from at least partial involvement in some of the many types of damage implicated by circumstantial evidence leads to the conclusion that acidic deposition must be considered a significant threat to the environment.

Many direct contact and indirect effects of acidic precipitation on forest productivity have been postulated based on fundamental responses of biological systems to acidity and other stresses. Growth patterns of mature forests in parts of Europe and North America, including the mountains of eastern Tennessee, have been altered in recent decades. Potential direct effects of acidic precipitation include those associated with seedling establishment and early growth, thinning of protective leaf coatings, changes in chlorophyll content, and interference with pollen development or seed germination. Acidic deposition may also be involved in decreasing the availability of nutrients to trees and increasing the availability of toxic metals from the soil. Acidic deposition may be involved in complex, synergistic interactions with primary gaseous pollutants, airborne toxic metals, climatic factors, and other site-specific variables that may affect tree growth or weaken trees and lead to secondary damage by insects or diseases. Changes in forest growth could be purely circumstantial and not related to acidic deposition, but it is much more likely that there has not yet been adequate linking of the very complex association of multiple and interactive factors involved and the subtle and chronic responses.

Direct damage to the foliage of some agricultural crops has been observed as a result of highly acidic simulated precipitation, but these direct effects have not been documented in the field. Available experimental data are not adequate to define the effects of acidic deposition; however, research indicates that any potential effects on soil acidity or soil nutrients are likely to be insignificant compared to the effects of agricultural practices such as nitrogen fertilization.

Available studies indicate that acidic deposition affects water quality in the same complex manner as it affects other areas of the environment--as a contributing factor, not the single cause. Data suggest that some high-elevation streams and lakes in Canada and the northeastern United States are becoming increasingly acidic. Studies indicate somewhat less clearly a trend of increasing acidity and decreasing alkalinity in portions of the Southern Blue Ridge Province in the Tennessee Valley. Short-term acidification of surface waters in North Carolina from runoff of heavy rains has been documented by TVA studies. The data from these studies did not rule out acidic deposition as a contributing factor; however, they provided strong evidence that the most significant short-term contributor is the soil of the forested watershed. Acidification of lakes and reservoirs has been circumstantially attributed to acidic deposition of air pollutants from distant sources, but the relative importance of nearby sources and natural terrestrial and aquatic processes is not known. People who drink acidic water, whatever the source of acidity, are considered at risk of increased intake of lead and possibly cadmium and aluminum that may contaminate the source or that may be dissolved from components of the distribution system.

Of all the potential effects of acidic deposition perhaps none is of greater emotional or scientific concern than the suspected role in the decline of fish populations; however, because of the complex interacting processes, there is perhaps greater uncertainty about effects on fish than on any other component of the ecosystem. Acidity alone or in combination with other factors can cause lethal or sublethal effects on adult fish and may reduce reproductive and developmental success. Some lakes are already too acidic to support fish, and some lakes are considered to have lost fish as a result of recent increases in acidity. Many lakes are considered susceptible to increased acidification and loss of fish, including some in the Southern Blue Ridge Province. Concern about these Valley fisheries is related to observed spinal deformities in smallmouth bass, trout mortalities in aquaculture facilities, decline in the range of brook trout, and possible aggravation of existing water quality effects on fisheries.

ASSESSMENT OF ENVIRONMENTAL EFFECTS OF ACIDIC DEPOSITION

Introduction

This document assesses potential environmental effects of acidic deposition. The perspective section places the implications of environmental damage by acidic deposition within the context of other complex physical and chemical processes that may affect soils, waters, forests, fisheries, water supplies, and agricultural crops. From the perspective of TVA's assessment of presently available knowledge, acidic deposition is very likely a contributing factor but not the only factor involved. This is especially significant because there is little direct evidence of acidic deposition effects and because TVA has no direct evidence of a link between acidic deposition and effects upon resources in the Tennessee Valley.

The document includes sections that discuss environmental effects on forests, crops, water quality, and fisheries and the processes by which these effects may occur. The purpose of these sections is not to provide an exhaustive listing of all reported effects but to provide discussion of the results of some selected investigations and studies that TVA believes to be professionally and scientifically credible and a general summary of the overall implications of these studies.

The document does not assess the significance of acidic deposition relative to other causitive factors or weigh the benefits of controls or environmental risks encountered because of the delay or lack of controls. However, such risks are clearly implied.

Perspective

More than a century ago, a British chemist noted damage to plants and materials, attributed it to "sulfur acid" in the air, and coined the term acid rain. A quarter century ago, Scandinavian scientists investigating declining yields from forests and lakes noted an apparent increase in the acidity of rainfall and surface waters. They postulated that urban and industrial pollutants were directly responsible for increasing the acidity of precipitation, which in turn was directly altering conditions in the terrestrial and aquatic environments and reducing biological productivity. About a decade ago, many scientists independently attempting to account for a wide range of environmental changes in widely scattered parts of the world noted similar empirical support and preliminary experimental evidence for this postulate.

Most scientists carefully qualified their findings as tentative and based on incomplete information. However, worldwide attention was focused on the potential for ecological disaster, and the reservations and caveats were ignored. Preliminary conjecture was accepted as fact in some cases, and acid rain became an emotional as well as a scientific issue.

Subsequently, during the period of critical review that is an integral part of the scientific process, new studies challenged the validity of many earlier studies. Scientists pointed out that new measurements had been compared with scattered historical data that were in many cases not directly comparable because they involved significant differences in factors such as analytical techniques, climate, meteorology, season of the year, time of day, bedrock geology, soil type and depth, vegetative cover, and land use. Measured levels of acid rain were calculated to be insufficient to account for some of the environmental changes attributed to them. Inconsistencies were noted--studies of sediment samples and other evidence showed that some of the lakes in question had become acidic hundreds or even thousands of years before the increase in combustion of fossil fuels, and some lakes became acid while closely neighboring lakes exposed to identical precipitation under apparently similar conditions remained unchanged. Estimates of the extent and severity of environmental change were reassessed, and the term acid rain became acidic deposition in recognition of the complexities of the issue.

Critical review revealed that the issue is more complex than it first appeared, indicated that atmospheric deposition is one likely factor but not necessarily the only factor that must be considered, and mapped the course for experimental investigation. As a result, hundreds of new research projects have been undertaken in many parts of the world to examine in greater detail the environmental processes that are involved.

Each type of investigation is subject to inherent limitations. Field observations of conditions at a site before and after acidification is suspected to have occurred are complicated because historical data are sparse and of questionable validity, because measurement techniques have changed and do not produce directly comparable results, and because changes in land use and other factors during the course of the acidification process make it difficult to isolate the effects of acidic deposition from those of other variables. In contemporary comparisons of similar environments thought to exhibit different degrees of acidic effects, it is also difficult to separate the effects of acidic deposition from the effects of the various factors that may be involved but that cannot be controlled. Field experiments focused on modifying one variable may overlook effects caused by the interaction of several other variables that cannot be controlled. For practical reasons, such field experiments are limited to a few months or a few years, while regional acidification occurs over many years or decades, and the compression of the time scale may produce misleading results. Controlled experiments that rely upon simulated acidic precipitation applied at a greatly increased rate or at a greatly increased concentration are subject to similar questions. Laboratory experiments that carefully control all variables other than the one being evaluated may miss the effects of interaction among several variables and may be limited by the effects of the artificial habitat and the eliminatic natural competition and interaction among various species.

Results obtained from one type of experiment at one site or in one under one set of conditions for one species cannot be extrapolated general conclusion regarding the entire question of acidic deposit effects. Each conclusion from each study becomes the subject for a cycle of critical review and further experiments to resolve uncertai

Those who are responsible for making decisions regarding a suspected to the public welfare desire clear and certain proof of the nature extent of that danger. Science seldom provides the luxury of such lutes. Instead, it provides circumstantial evidence that must be we and balanced to indicate probability.

Intensive investigation has not substantiated the existence of a si unbroken chain of cause and effect. However, it has traced here and in the complex web of the environment what is believed to be a com factor. Most leading scientists, including those in the Tennessee V Authority, now recognize as a working hypothesis that acidic deposi under certain conditions can directly and indirectly contribute to c types of long-term damage to sensitive ecosystems in many regions o world, including portions of the Tennessee Valley.

There is a considerable weight of circumstantial evidence that impli acidic deposition as one of the contributing factors in a long lis effects on soils, vegetation, surface waters, aquatic organisms, drinking water. In almost every instance, there is also circumstan evidence implicating other processes and pollutants, some natural an related to human activities. Not all the suspected effects have b observed in all apparently similarly suspectible environments that been studied, and significant differences between the results of app similar investigations of the same suspected effects have not yet resolved. It may be a long time before research pinpoints the rela significance of the multiple factors that may be involved in each ty damage. However, these uncertainties and the need for continuing re do not negate the present significance of acidic deposition as one c factor that appears to be involved in varying degrees in many diffe environmental impacts. The probability of cumulative impacts from least partial involvement in some of the many types of damage now su ted leads to the conclusion that acidic deposition must be consider significant threat to the environment.

Forests

Many direct and indirect effects of acidic precipitation on forest p tivity have been postulated based on fundamental responses of biolo systems to acidity and other stresses.

Based on experimental evidence with simulated precipitation, a wide range of plant species is believed to be sensitive to direct contact injury, while other species have been noted to be tolerant of equally elevated levels of acidic precipitation. Research conducted by TVA has detected no direct effects of acidic precipitation on seedlings of three important forest species in the Tennessee Valley. Factors evaluated included morphological factors such as changes in thickness of the wax covering of leaves and physiological responses such as changes in chlorophyll content or respiration. TVA data as well as the data of others suggest that generalizations about sensitivity to direct injury may be quite difficult, because most work indicates response to be species specific. Another area of potential direct injury is pollen development, seed germination, and seedling establishment. Evidence to date indicates that the seedling establishment stage may be the most sensitive to direct effects of acidic precipitation, followed by the early seedling growth stage for some species. While neither of these potential effects would be important in causing short-term effects on productivity, both would be significant in the long run, in terms of maintaining the present mix of tree species in the forest and maintaining long-term productivity.

Various studies have presented data indicating that species composition or population densities of insect groups are altered in areas of high air pollution stress. However, little information is available on the direct effects of acidic precipitation on either harmful or beneficial insects. Research on the response of plant diseases has indicated that a given dose of a specific air pollutant may be stimulatory, neutral, or detrimental to the growth of a particular virus, bacterium, or fungus. The most likely effect is an indirect or secondary effect; if trees are weakened by acidic deposition, alone or in combination with other factors, they may be more susceptible to invasion by insects or disease.

Because the level of productivity achieved by a particular forest is a result of the interaction of a number of factors, barring the impact of a significant direct contact effect, it is much more likely that any change in productivity will be the result of the additive indirect effects of several factors. Two such factors identified as having a high probability of impact are (1) decreases in the availability of essential nutrients or increases in the availability of toxic metals and (2) interactive effects of acidic deposition with gaseous pollutants or interactions of gaseous pollutants with changes in nutrient availability. Most research to date suggests that possible changes in productivity are associated with chronic exposures or changes. As is true of most chronic environmental problems, it is difficult to isolate a single factor as being responsible for the change. This problem is made even more difficult by the fact that some of the precursors of acidic deposition (sulfur dioxide and nitrogen oxides) are also toxic to plants in the gaseous form in which they are emitted as primary pollutants. The possibility of synergistic interactions of pollutants is also a real possibility, adding further complexity to the question.

To date, the greatest research emphasis in assessing potential changes in forest productivity has been directed toward nutritional effects.

Acidic deposition can both add essential plant nutrients to the soil and remove others from it. Another aspect of the question is the potential for increased acidification of forest soils and the subsequent changes in soil chemistry, especially increased availability of aluminum and other metals that are toxic to plants. TVA research has indicated that changes in soil nutrient status do appear to occur in conjunction with simulated acidic deposition treatments, with certain elements such as calcium being redistributed within the soil profile. However, the same study detected no effects on the growth of tree species that were evaluated. Studies have shown that some soils in Tennessee are no longer able to absorb additional sulfur; essential nutrient anions such as calcium may combine with unabsorbed sulfate cations and be lost from the soil. Field studies have yet to link observed or suspected changes in fertility to suspected or anticipated changes in productivity; the suspicion continues, but the means of verification have not been developed. Ulrich has recently documented increases in concentrations of aluminum in the soil and the soil solution at forest sites in West Germany. These changes are of significance to forest productivity because plant roots are sensitive to elevated levels of aluminum, and several tree species have suffered either death or decline in growth in that area.

Although considerable weight is still given to changes in fertility and effects of aluminum as potential causes of reduced productivity, more recent hypotheses include interactions of acid deposition with other pollutants such as ozone, sulfur dioxide, and nitrogen oxides. Studies in the Great Smoky Mountains of east Tennessee have indicated that productivity of red spruce, shortleaf pine, hemlock, hickory, yellow birch, pitch pine, and Fraser Fir is declining. The researchers noted that these declines, together with those in New England, suggest decreased productivity has been occurring over the past two decades. A combination of pollutants, including acidic deposition, ozone, and trace metals, was proposed as a possible cause. The impact of cloud contact with trees in high elevation forests has been identified as a potential factor in the declining productivity indicated by these studies. Studies conducted at a site in the Great Smoky Mountains National Park indicated that the concentration of iron in tree rings was elevated during the period 1863 to 1912 and that the trees showed a simultaneous decline in growth. A smelter approximately 90 kilometers upwind began operations in 1854 and, by court order, reduced emissions in 1910. This is further indication that emissions of acid precursors and airborne trace metals may affect metal uptake and the growth of trees.

Early studies by TVA in the vicinity of one of its coal-fired power plants indicated that white pine productivity was reduced near the plant; rather than a single pollutant, a mixture of pollutants is suspected as the causal agent. Based largely on information gathered in Europe and the northeastern United States, it is now widely thought that forest decline is the result of possible synergistic interactions among gaseous pollutants, acidic deposition, metal toxicity, and excessive loss of nutrients such as magnesium and calcium. While there does not appear to be a strong relationship with changes in the amount of precipitation (drought), interactions with other climatic variables cannot be ruled out at this time.

In summary, research to date indicates that direct contact effects attributable to acidic deposition are limited. The most serious potential effects are associated with seedling establishment and early seedling growth. The net effect of acidic precipitation on soil fertility depends on a number of site-specific factors. Acidic deposition in sufficient amounts will likely reduce productivity on sites where levels of nitrogen and sulfur are adequate but where levels of other nutrients are deficient. TVA experience documents, as does the work of others, the potential for changes in productivity. These changes have been demonstrated only in controlled studies, not in the field.

There is no direct proof that acidic deposition is now limiting growth of forests. Field studies of mature forests show that growth patterns have been altered in recent decades in many North American and European forests. Declines in productivity of several species of trees in the higher elevations of eastern Tennessee have been documented. Although to date no clear link has been established between these changes in forest growth and acidic deposition, such a relationship has not been disproved. Recent changes could be purely circumstantial and not in any way related to acidic deposition, but it is much more likely that there has not yet been adequate linking of the very complex association of multiple and interactive factors involved and the subtle and chronic responses.

Crops

Acidic deposition may affect crop productivity by two routes: (1) Indirectly, through effects on the soil, soil microorganisms beneficial to crop productivity, and plant pests; and (2) directly, through contact with the plant foliage or other plant surfaces.

Acidic deposition may affect crop productivity by accelerating: (1) acidification of soils to levels that are unsuitable for production of plants that require neutral or nearly neutral soils or (2) leaching of plant nutrients such as calcium and magnesium. However, there appears to be consensus among plant scientists that these effects of acidic deposition on agricultural soils are insignificant compared with those caused by cultural practices such as nitrogen fertilization.

Investigations of the effects of simulated acidic deposition on various plant pests, including insects and diseases, have shown both increases and decreases in pests. There is little information on the effects of acidic deposition on soil microorganisms beneficial to crop plants. However, it has been reported that simulated deposition, at levels 10 times more acidic than average levels now occurring in precipitation over large areas of the northeastern and southeastern United States, reduced populations of beneficial nitrogen-fixing bacteria in some legumes.

Acidic deposition directly on the foliage and other surfaces of crop plants may adversely affect production through effects on photosynthesis, flowering, fruit set, and seed germination and possibly through other metabolic processes or through acceleration of leaching of nutrients from the foliage. However, no effects of acidic deposition have been documented under field conditions. There have been many investigations of the effects of simulated acidic deposition on crop and garden species under field and controlled environmental conditions. Results have been inconclusive, even for the same species or cultivar. In a few studies, yields of some crop species showed negative responses to acidic deposition; however, most studies indicate no effect on productivity from highly acidic simulated precipitation. Garden beets and carrots showed the most consistent reductions in yields at several levels of simulated acidity. Yields of "Pioneer 3992 field corn" and "Amboy" soybean decreased in response to some acidity levels and increased in response to others. In a large number of experiments, alfalfa, fescue, mustard greens, tomatoes, and wheat, and many other species produced increased yields, perhaps in response to a fertilizing effect of the nitrate and sulfate in the simulated rain.

Available experimental data are not adequate to define the effects of acidic deposition. Cultivars within a species can show a wide range of responses to a stress. Net response to stress is determined by the interactions of a multiplicity of cultural, soil, and climatic factors that have not been investigated with respect to acidic deposition.

In summary, direct damage to some agricultural crops has been observed at low pH under laboratory conditions, but available laboratory and field data are not adequate to define effects of acid deposition. Results tend to indicate that the effects of accepted agricultural practice outweigh potential impacts of acidic deposition.

Water Quality

Atmospheric deposition has been shown to increase the concentration of hydrogen ions and other substances in surface waters near point sources of air pollutants. One of the most cited examples of this phenomenon occurred in the Tennessee Valley at Copperhill, Tennessee, where emissions from a copper smelter resulted in acidification of surrounding soils and surface waters. Similar effects have been observed from smelter emissions near Sudbury, Ontario, where increased levels of acidity, sulfate, copper, and nickel have been reported in lakes in the area.

A large body of circumstantial evidence has also been compiled to suggest that long-range transport of acids has caused acidification of freshwaters in North America. For the most part, only extrapolations of these data have been made to the southeastern United States. Most of the studies were performed in Scandanavia, Canada, and the northeastern United States.

The effect of acidic deposition on the water quality of streams and lakes depends not only on what is deposited, but also on its interaction with all components of the terrestrial system that it contacts before it is discharged into the aquatic system. The effect of the terrestrial system is probably greatest for lake systems with relatively large watershed areas and relatively small lake areas, where most of the precipitation comes into contact with the terrestrial system before reaching the lake. The effect of acidic deposition is potentially greatest for lakes with no defined inlet and with relatively large areas of lake surface and relatively small watershed areas--where more of the precipitation falls directly on the lake without ever coming into contact with the terrestrial system. The direct effect of acidic precipitation on such lakes is now being investigated in the Adirondack region of New York and in upper midwestern States.

Snowmelt has been implicated in causing direct effects on aquatic systems. In two Adirondack lakes, alkalinity decreased during snowmelt because of dilution of base cations and an increase in nitric acid in the lake. Researchers concluded that the primary cause of the increased concentration of nitrates was release of accumulated nitrates from the snowpack. An analysis of two additional snowmelt incidents supported this conclusion.

Short-term acidification of surface waters from runoff of heavy rains has been documented. A TVA study in the Raven Fork watershed near Cherokee, North Carolina, concluded that increased stream acidity following heavy rainfall, possibly in combination with resulting increases in aluminum concentrations, contributed to fishkills. However, the data provided strong evidence (1) that the forest soil in the watershed area is strongly buffered by weak organic acids against changes in hydrogen ion concentration from addition of hydrogen ions from external sources such as the strong acids in atmospheric deposition, and (2) that the forest soil controls hydrogen ions and aluminum concentrations in the creek water following storms. These results may not be applicable to other watersheds. The Raven Fork watershed is a mature, coniferous forest with acidophilic species such as rhododendron that cycle large amounts of aluminum, and the highly acidic soils (pH 3.7 to 4.1) are high in exchangeable hydrogen, organic matter, and aluminum. The data did not rule out the possibility of acid deposition as a contributing factor.

The long-term relative effects of acidic deposition on freshwaters is more difficult to assess. Some data support the hypothesis that internal generation of hydrogen ions in watersheds can be greater than inputs of hydrogen ions from the atmosphere. Factors commonly considered to make watersheds susceptible to acid deposition are the same factors long known to acidify soils through natural processes. Therefore, some researchers believe that natural soil formation is often more important than acid deposition in determining the acidity of lakes and streams. Other researchers indicate that atmospheric sources of acids can amount to 50 percent of that generated internally.

It is well known that lake ecosystem processes are very important in influencing the generation or consumption of akalinity and internal production of alkalinity in the epilimnion of a lake. Internal processes in the hypolimnion are capable of either depleting or increasing alkalinity. Processes that occur in lake sediments may also affect the acid-neutralizing capacity of lake water, although these processes are not well documented.

Identification of areas with aquatic systems potentially sensitive to acidic deposition has been approached using several related methods that may be classified into three general categories--those using soil characteristics, bedrock geology, and actual values of surface water alkalinity. Sensitive areas in North America have been roughly approximated on the basis of bedrock geology. Large areas of eastern Canada were considered sensitive, as were the Northeast, the upper Midwest, the Pacific Northwest and the Rockies, and the southern Appalachians. Soil characteristics were also used to locate regions in the eastern United States potentially sensitive to acidic deposition with somewhat similar results. Surface water alkalinity data have been correlated with physiography, geology, soils, climate, and human factors to predict mean annual alkalinities for all regions of the United States, even those without alkalinity data. This method, in effect, combines several other important factors and, like the other techniques, suggests that the Southern Blue Ridge Province in the Tennessee Valley contains sensitive aquatic systems. It has been shown, however, that several other factors may influence sensitivity to acidification, including topography, the ratio between lake area and watershed area, watershed vegetation, land use, surface water quality, and aquatic vegetation. The relative importance of each characteristic depends on site-specific conditions.

Numerous investigators have evaluated available surface water quality data in areas receiving acidic deposition. In some areas of the northeastern United States and eastern Canada, a large number of lakes have reportedly experienced increasing acidity as a result of acidic deposition. TVA recently completed a preliminary study of the trends in pH and alkalinity of surface waters in the Southern Blue Ridge Province. A decline averaging 0.02 pH unit per year was observed for high-elevation, low-alkalinity streams for which sufficient data were available. Acidic deposition is a potential contributor to the observed changes in water quality. Higher rainfalls in recent years may also have played a significant role in observed trends. These data are now being investigated in more detail.

A consistent drawback of these types of studies is the lack of documentation available for the "historic" data due to errors associated with a comparison of old and new data. This often precludes making an absolute statement that individual systems have become more acidic. One recent study, however, reviewed water quality records over a 10- to 15-year period where consistent sampling and analytical methods were applied. The results provide evidence that observed patterns in water quality trends reflect regional changes in the rates of sulfur dioxide emissions. The body of knowledge does provide circumstantial evidence for recent acidification in the northeastern United States and Canada. Supporting this circumstantial evidence is the analysis of diatoms in lake sediment cores. These paleolimnological techniques have been applied in Norway with apparent success in providing indications of acidification trends. Researchers are now investigating the same techniques in the northeastern United States and the Southern Blue Ridge Province.

Health risk in drinking water supplies is related to the source of water and the treatment and distribution of the supply. Data on im of acidic deposition on water supplies are extremely scarce. Avai studies are based on data from impacts to aquatic ecosystems. Two drinking water impacts may exist--contamination of water at the sou increased corrosivity that in turn may cause dissolution of lead cadmium. A frequently cited example of the latter is the case of B Massachusetts. The high acidity of the drinking water supply, what the cause, contributed to lead poisoning of children where lead w distribution pipes were in use. People who obtain drinking water roof catchment cisterns have potential risk of increased intake of in areas receiving acidic deposition, regardless of terrestrial fac It has been reported that lead and, less frequently, cadmium accumu in sediments that collect at the bottoms of cisterns and could appe the drinking water.

Aluminum in water supplies has long been thought to be innocuous, recently aluminum in water used for dialysis treatment has been asso with senile dementia and dialysis encephalopathy. Due to the relati between aluminum and these ailments, the development of a maximum co nant level for aluminum in drinking water has been suggested in t *Federal Register*.

In summary, data now available provide circumstantial evidence that surface waters in eastern North America are becoming increasingly ac particularly lakes in the northeastern United States and Canada. Da the most potentially sensitive region in the Tennessee Valley, the S Blue Ridge Province, also indicate a trend of declining pH and alkal in high elevation streams; however, data are insufficient to suppor conclusive statement. The cause of acidification has generally be attributed to atmospheric inputs from long-range sources; however, relative importance of inputs from internal, natural, or nearby atmo sources is not known. People who drink water from acidic water sou should be considered at risk of increased intake of lead and possibl mium and aluminum. Shallow groundwater sources in areas potentially sitive to acidification are most likely to be adversely impacted. T available studies indicate that acidic deposition affects water qual in the same complex manner as it affects other areas of the environme as a contributing factor, not as a single cause of the environment impacts.

Fisheries

Of all the potential effects of acidic deposition, perhaps none is greater emotional or scientific concern than the suspected role in t decline of elimination of fish populations. Because fish are near t end of a long and complex tangle of interacting direct and indirec processes, however, there is also perhaps greater uncertainty abou effects on fish than on any of the other components of the ecosyste

Laboratory studies cannot establish a cause-and-effect relationship between acidic deposition and loss of fish populations in the natural environment, but they can and have identified various mechanisms by which acidity can affect fish. It is clear from laboratory studies that acute exposure of adult fish to various levels of acid stress alone can cause lethal or sublethal toxic reactions that affect respiration, acid-base regulation, and ionic and osmotic regulation. The combined effects of acute exposure of adult fish to acid stress, high levels of toxic metals (especially aluminum), and low levels of calcium are less well understood but appear to include loss of salts from blood plasma, gill damage, and copious secretion of mucous that clogs the gills and may lead to suffocation or selectively alter the exchange of ions across the gill surface. Different species, as might be expected, exhibit different degrees of sensitivity or tolerance. Lower levels of chronic acidity or transient surges in acidity in combination with toxic metals may prevent release of mature eggs, fertilization, or normal development during early life stages, thereby reducing reproductive success.

It is clear that some lakes are sufficiently acidic that they will not support some or any species of fish. The actual number and total acreage of such lakes [illegible] relatively small, however, and it is not clear how many have been acidic for hundreds or thousands of years, how many may have become acidic more recently, or how many became too acidic for fish as a result of natural factors. In only a few cases are field data available showing that fish populations declined as acidity gradually increased.

There are indications that some lakes and rivers have lost sport fisheries in recent years because of increased acidity. A number of acidic lakes in New York no longer support brook trout. Salmon populations have declined in rivers in Nova Scotia. Loss of fish populations from acidified Canadian lakes near the Sudbury smelter have been documented. In most places there are inadequate historical or modern fisheries data to allow any reliable assessment of possible changes in total fish populations or the diversity and relative abundance of species present.

There are also indications of increasing acidity in a large number of other lakes and streams where loss or decline of fish populations has not yet been documented. There are, in addition, thousands of lakes in North America that must be considered potentially susceptible to increased acidification and decline of fishery resources; these include lakes in Canada, the Adirondacks and other parts of the northeastern United States, the upper midwestern United States, and the Southern Appalachians. Many scientists consider it highly credible that many of these susceptible lakes could become increasingly acidic during coming decades as a result of low capacity to buffer additional acidity from acidic deposition, from natural acidification processes, or from a combination of sources.

Recent assessments by TVA and others indicate that fisheries in the Southern Blue Ridge Province of the Tennessee Valley may be susceptible to the effects of acidic deposition. Several observations in this portion of the Valley, when viewed in light of reported effects on fish

populations in the northeastern and midwestern United States, C
Scandinavia, raise genuine cause for concern that a link may exi
these problems and acidic deposition. These problems include
unusually high incidence of spinal deformities in smallmouth b
lected from Chatuge Reservoir in north Georgia and Fontana Rese
North Carolina; (2) rainbow trout mortalities in aquaculture fac
North Carolina following rainfall events; (3) decline in the rar
native Appalachian brook trout over the past several decades; a
cern that added stress from acidic deposition may compound pro
areas where fish populations are already stressed by other envi
factors such as toxic discharges from industrial operations and
centrations of dissolved oxygen.

In the past, concerns about fish habitat and fish populations
Tennessee Valley tended to focus upon the potential effects do
from urban and industrial centers in the most developed areas a
Tennessee River and its principal tributaries. As a result, e
fisheries data are available from many years of routine and spe
veys of these areas. The fisheries now considered most suscep
potential effects of acidic deposition, however, are generally
elevation streams, lakes, and headwater reservoirs in remote a
tively undeveloped portions of the Southern Blue Ridge Province.
there has historically been less concern about potential damage
undeveloped areas, few fisheries surveys have been conducted
Therefore, there is not an adequate historical data base for co
with recent data to indicate the nature or extent of any long-te
that may have occurred in these fisheries in reponse to increase

Data on smallmouth bass from Chatuge Reservoir confirmed the obs
of fishermen that increased numbers of deformed fish have been f
the past five years. Blue Ridge Reservoir, located nearby, ha
quality and other characteristics similar to those in Chatuge,
deformity of smallmouth bass has been reported or identified by
The Chatuge Dam discharge has a median pH of 6.0 and a median
level of 1.3 milligrams per liter, while the median values fo
Blue Ridge Dam discharge are pH 6.6 and 1.1 milligrams per lite
water quality characteristics indicate both reservoirs should b
their ability to neutralize acids.

The absence of significant industrial or agricultural sources c
contaminants in the Chatuge watershed, along with the fact that
water chemistry of the reservoir is of a nature that would be ex
be sensitive to acid input, has led to speculation that the high
of spinal deformities may be attributable to acid stress. Rese
shown that such deformities can be caused by acid stress as we
number of other environmental factors, including disease, geneti
tion, certain metals and pesticides, and extreme temperature flu
at sensitive life stages.

Data collected during 1983 indicated the following information.

1. About 29 percent of the Chatuge smallmouth bass collected ha deformities. Deformities were only detected in fish 3 years older. No deformities were detected in fish from Blue Ridge

2. No unusual concentrations of pesticides were detected in fi either reservoir. The fish appeared healthy, except for th deformity.

3. The vertebrae of yearling bass from Chatuge were weaker than yearling bass from Blue Ridge. (Studies by others have indi chronic acid stress may interfere with metabolism of calcium demineralization of bone.) The data also suggest that Chat have lower plasma calcium concentrations than Blue Ridge

4. Smallmouth bass from Chatuge had five to nine times greate body zinc concentrations than those from Blue Ridge and othe voirs. No other metals were found in elevated concentrat (Laboratory water quality studies reported in the literatur linked zinc with spinal deformities, but no literature has b that correlates whole body zinc concentrations with bone def

Studies in 1984 have been expanded to other Blue Ridge Province r including Fontana, Santeetlah, Nantahala, Thorpe, and Nottley. P data seem to confirm the greater than 20 percent incidence of def in Chatuge and indicate a 28 percent incidence in Fontana. No de have been noted in fish collected from Blue Ridge and Santeetlah.

The second concern is trout mortalities in aquaculture faciliti survey of operators of fish hatcheries supplied with water from streams draining the Great Smoky Mountains National Park invent numerous reports of fish losses in recent years. Some of these were reported to be associated with specific storm events.

Perhaps the largest and best documented case occurred in the Rav watershed near Cherokee, North Caroline where about 50,000 rainbo died at a commercial facility and an additional 524 trophy-size died in three Cherokee Indian ponds following eight storm events March 31 and December 2, 1981. Strengthening the assumption that had been responsible for these fishkills, no further fishkills o at the commercial facility after the practice of adding lime to t water was begun, and no more trophy trout died after water from springs was routed to the ponds during subsequent storms. Becaus cern that these fishkills might be caused by acidic deposition, T took studies to determine the cause. The surveys of Raven Fork that hydrogen ion and aluminum concentrations in the creek follow events of one inch or more increased to levels reported to be to trout. The results of a 6-month investigation of the watershed in that most of the stream acidity was attributable to weak organic a natural origin but did not rule out the possibility that acidic de may have been a contributing factor in the trout mortalities.

Another concern is the decline of the Appalachian brook trout, the only trout species native to the mountain streams of the Southern Blue Ridge Province. Its range has declined drastically during the past 100 years because of competition with introduced rainbow trout and poor logging and mining practices. Acidification of poorly buffered streams would further the decline of brook trout populations as well as populations of imported species such as rainbow and brown trout.

A final concern is the possible effect of acidic deposition on existing fishery problems. The development of trout fisheries below TVA dams in the Southern Blue Ridge Province has generally been successful. However, their ultimate usefulness has been hindered by problems with low dissolved oxygen and intermittent flow during late summer and fall. Industrial operations and the presence of toxic materials are also contributing to the problem in some mountain trout streams. Changes in water quality that might be caused by acidic deposition would aggrevate these problems and reduce the usefulness of these fishery resources.

In summary, circumstantial evidence provides cause for concern that a link may exist between acidic deposition and fish populations. Laboratory studies show that acidity alone and acidity in combination with other factors can cause lethal and sublethal effects on adult fish and may reduce reproductive or developmental success. It is clear that some lakes and are too acidic to support fish. It is considered likely that some lakes have suffered loss or decline of fish populations as a result of recent increases in acidity. Many lakes are considered susceptible to increased acidification and possible decline in fish populations. Certain lakes and streams in the Southern Blue Ridge Province in the Tennessee Valley are among those considered susceptible to increased acidity, including the potential effects of acidic deposition. Observations of spinal deformities of smallmouth bass in Chatuge and Fontana Reservoirs, trout mortality in North Carolina aquaculture facilities, and a decline in the range of native brook trout, combined with the possibility that increased acidity might aggravate existing stress on fisheries from toxic industrial discharges and low dissolved oxygen levels and intermittent flows below certain dams, lead to concern about fishery resources in the Tennessee Valley region.

Office of Natural Resources and Economic Development
January 31, 1984

APPENDIX H

Statements Submitted for the Record to the Senate Committee on Energy and Natural Resources

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1. Michael Baly, Vice President, Government Relations, American Gas Association, Arlington, Virginia.

2. Dr. Leon Green, Jr., Vice President, Clean Coal Coalition, Inc. Washington, D.C.

    a. "Sulfur Emission and Acid Rain: A Least-Cost Approach to the Problem", by Leon Green, Jr., reprinted from Public Utilities Fortnightly, December 8, 1983.

    b. "Coal Cleaning: The First Step", by Leon Green, Jr., from the First International Conference on Acid Rain, March 27-28, 1984, Washington, D.C.

    c. "Evaluation of the Environmental and Other Benefits of The Select Use of Natural Gas", Environmental Research and Technology, Inc. Washington, D.C. November 1983.

    d. "Federal Tax Issues Affect Deployment of Coal Cleaning Technology Options", from the Clean Coal Coalition, Inc., Washington, D.C. January 13, 1984.

3. William A. Molini, Chairman, Colorado River Wildlife Council.

4. Robert E. Cole, Vice President, Government Affairs, Kaiser Aluminum and Chemical Corporation.

5. James C. Wilson, President, Rocky Mountain Energy, Broomfield, Colorado.

Richard

Official Committee File

American Gas Association

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Michael Baly III
Vice President
Government Relations

May 11, 1984

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
MAY 14 1984
[illegible]
WASHINGTON, D.C. 20510

The Honorable James McClure
Chairman
Committee on Energy and Natural Resources
U.S. Senate
Washington, D.C. 20510

Dear Mr. Chairman:

The American Gas Association noted with interest the Energy and Natural Resources Committee's April 30, 1984 oversight hearing on acid rain. We would like to present for the Committee's consideration an easily-implemented and cost-efficient technique for reducing sulfur dioxide emissions -- the Select Use of Natural Gas.

Attached is our statement discussing the Select Use of Natural Gas for environmental compliance. We would appreciate having it made a part of the Committee's April 30 hearing record.

If you or your staff have questions about the select use of natural gas, please feel free to contact me.

Respectfully,

Mike Baly

Michael Baly III

MB/dl

Enclosure

Mike Baly
Vice President
Government Relations
American Gas Ass.

STATEMENT OF
THE AMERICAN GAS ASSOCIATION
BEFORE THE
SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES
ON METHODS TO REDUCE SO_2

April 30, 1984

- -

Introduction

Mr. Chairman and members of the Committee:

The A.G.A. is a national trade association composed of nearly 300 natural gas distribution and transmission companies serving over 160 million U.S. consumers.

On behalf of both our members and our consumers, we would like to put before this Committee our support for an easily implemented and economical technique of reducing sulfur oxide (SO_x) air pollution which has been successful at many facilities. We call this strategy the Select Use of natural gas. It involves combusting natural gas -- which emits virtually no sulfur oxides when burned -- along with more polluting fuels, such as coal or high sulfur oil at a given plant site. Clean burning natural gas can offset or reduce the amount of air pollution that would have been emitted if just coal or high sulfur oil were burned.

Many bills have been introduced in both the House and the Senate to reduce sulfur oxide emissions. We believe that sulfur oxide reductions should be achieved with performance standards, leaving the plant operator free to choose the most efficient control strategy for the particular plant.

The most efficient control strategy for a particular plant depends on factors at that plant. As long as environmental goals are met, it makes sense to let the plant operator choose the control strategy that best fits the plant. Select use of gas, either on a interim or a permanent basis has a place along with low sulfur coal blending, coal washing, scrubbers.

What Is Select Use?: An Explanation of the Strategy

Natural gas is an extremely clean burning fuel. It emits virtually no sulfur oxides or particulates when burned. Its carbon dioxide, carbon monoxide, nitrogen oxide, and non-methane hydrocarbon emissions are all lower than oil or coal. For example, on the average a large gas boiler (either industrial or power plant) emits only .0006 pounds of sulfur dioxide (SO_2) per MMBtu, while a boiler on an average grade of residual fuel oil (1.5% sulfur) emits 1.6 lbs SO_2/MMBtu. A similar boiler operating on 2% sulfur coal emits 3.4 lbs/SO_2/MMBtu.

A good example is a project in the city of Pittsburgh. A consortium of public bodies, including the Carnegie Mellon University, has a district heating plant for steam heat that is the equivalent of a 175 Mw powerplant. The plant has six boilers: (a) two that burn .7% low sulfur coal; (b) one that burns 100% natural gas; and (3) three that burn natural gas/coal mixtures. In 1983, the plant used 22% natural gas and 78% coal in a major urban area. Air quality limits are set by Allegheny County and are very strict for SO_2. Since the facility has no room for are very strict for SO_2. Since the facility has no room for scrubbers, select use of gas with coal was the site operators' preferred control strategy. At a cost of $6 per 1,000 lbs. of steam, the owners consider their system both efficient and inexpensive.

In another well-known case, the Narragensett Electric Company in Rhode Island used the clean burning attributes of natural gas to offset emissions from a switch to a higher sulfur oil. The utility operated two boilers on expensive low sulfur oil. In order to reduce fuel costs, it switched one boiler to high sulfur oil and the other to natural gas. By converting a single boiler to gas, the company was able to offset the increased SO_2 from the high sulfur oil and still comply with the area's strict SO_2 limits.

Select Use can be used with residual fuel oil, Eastern high sulfur or Western low sulfur coal. The following charts show the amount of natural gas (in percentages) that could be used with coal or oil, depending on variations in the sulfur content, with the stringency of local limits on SO_2 emissions (shown on the left axis). These data show the significant environmental benefits of using natural gas.

PERCENTAGE OF FUEL MIX REQUIRED TO BE GAS FOR VARIOUS GRADES OF COAL AND SO_2 EMISSION LEVELS

SO_2 SIP (lb./MMBtu)	Sulfur Content of Eastern Coal[2]				Sulfur Content of Western Coal[3]			
	.8%	1%	2%	3%	.8%	1%	2%	3%
0.6	53%	62%	81%	87%	61%	68%	84%	89%
0.8	37	49	75	83	47	58	79	86
1.0	22	37	68	79	34	47	74	82
1.2	6	24	62	75	21	37	68	79
1.4	–	11	56	71	8	26	63	75
1.6	–	–	50	66	–	16	58	72
1.8	–	–	43	62	–	5	53	68
2.0	–	–	37	58	–	–	47	65
2.2	–	–	31	54	–	–	42	61
2.4	–	–	24	49	–	–	37	58
2.6	–	–	18	45	–	–	32	54
2.8	–	–	12	41	–	–	26	51
3.0	–	–	5	37	–	–	21	47

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[1] *Select Gas Use for Environmental Purposes*, American Gas Association 20 (January. 1983).

[2] 12,000 Btu/lb.

[3] 10,000 Btu/lb.

PERCENTAGE OF FUEL MIX REQUIRED TO BE GAS FOR[1] VARIOUS GRADES OF RESIDUAL OIL AND SO_2 EMISSION LEVELS

SO_2 SIP	Sulfur Content of Oil				
(lb./MMBtu	.25%	.5%	1%	2%	3%
0.2	23%	62%	81%	90%	94%
0.4	–	23	62	81	87
0.6	–	–	43	71	81
0.8	–	–	24	62	75
1.0	–	–	5	52	68
1.2	–	–	–	43	62
1.4	–	–	–	33	56
1.6	–	–	–	24	49
1.8	–	–	–	14	43
2.0	–	–	–	5	37
2.2	–	–	–	–	30
2.4	–	–	–	–	24
2.6	–	–	–	–	17
2.8	–	–	–	–	11
3.0	–	–	–	–	5

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[1] *Select Gas Use For Environmental Purposes*, American Gas Association 21 (January. 1983).

Choosing the Most Efficient Sulfur Oxide Control Strategy: The Benefits of Natural Gas

With select use of gas, the cost of sulfur oxide reductions can vary from \$50/ton of SO_2 removed to over \$1000/ton. This range of costs is not unusual considering the many variables, such as state set emission limits, and fuel and equipment costs, which can change dramatically from site to site. A study by ICF, Inc. a consulting firm, postulated that fuel switching (high to low sulfur coal or oil) and scrubbing could result in control costs ranging from \$250 - \$2000/ton. When one considers that many select use options fall in the \$200 - \$400/ton range, the reader can immediately see that gas and coal or gas and high sulfur oil mixtures are often economical alternatives to scrubbing or fuel switching.

For completeness, we note that the ICF \$250 - \$2000 cost range for non-select use control options is as follows:

Representative Annualized Costs of SO_2 Reduction Alternatives*

Control Strategy	\$/ton SO2 Removal (mid-1982 dollars)
Shift from High- to Low-Sulfur Coal**	\$ 250 - \$ 300
Shift from High- to Medium-Sulfur Coal**	350 - 400
Shift from Medium- to Low-Sulfur Coal**	400 - 450
Shift from High- to Low-Sulfur Residual Oil	450 - 600
Shift from Unscrubbed to Scrubbed High Sulfur Coal***	400 - 500
Shift from Unscrubbed to Scrubbed Medium-Sulfur Coal***	600 - 1,100
Shift from Unscrubbed to Scrubbed Low-Sulfur Coal***	1,200 - 2,000

---

*Cost will vary considerably, depending upon region and plant size. Costs per ton presented in this table are intended to be representative of average control costs only.

**Costs include upgrading particulate removal equipment.

***Based on retrofit scrubbing costs for a 500-megawatt powerplant.

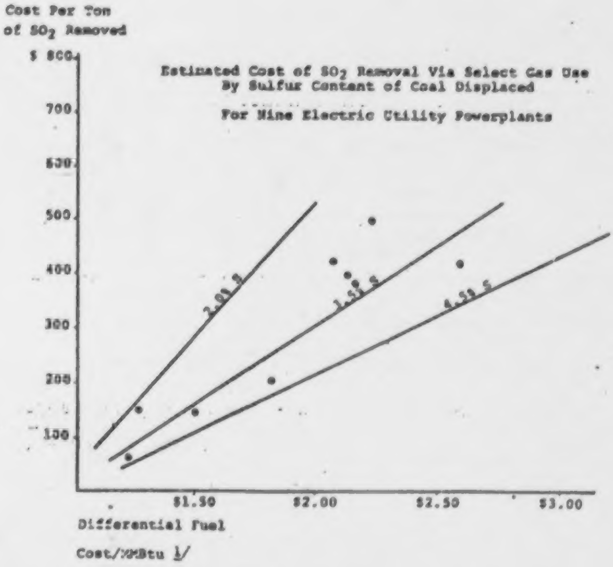
Source: ICF, Incorporated

We think, however, that ICF may have understated the costs of a massive switch to low sulfur coal. For example, the model tends to understate the costs of increased rail transportation. Also, the other effects of fuel switching need to be considered. These include unemployment in Eastern coal mines, plant derating, and increased solid waste disposal.

In many situations, but not in all or even necessarily most, select use can be the most economical control option. In addition to the quantifiable benefits of select use, we should also mention its intangible benefits. For example, select use is a flexible control strategy that can be combined easily with other technologies. Select use and low cost coal washing could reduce SO_2 by 50% or more while continuing to burn Eastern high sulfur coal as 70% or more of a plant's fuel. This is in sharp contrast to low sulfur coal fuel switching which could cut Eastern coal consumption to 25%, in the worst case.

Although the immediately preceding pages have been devoted to select use with coal, natural gas mixtures are also an excellent way to lower high sulfur oil emissions. There are hundreds of power plants and industrial facilities that could use gas/oil mixtures either in adjacent boilers, or in the same boiler. Professor Alex Green of the Interdisciplinary Center for Aeronomy and Atmospheric Sciences at the University of Florida estimated in

1980 that consumers could save $12.5 billion per year in electricity costs by switching 100% oil-fired powerplants to gas mixtures. (While the Green work is becoming dated, the bottom line is still clear: the potential savings are large.) The following chart graphically displays the site specific benefits of select use at nine powerplants.


Estimated Cost of SO_2 Removal Via Select Gas Use
By Sulfur Content of Coal Displaced

For Nine Electric Utility Powerplants

1/ Cost of Gas - Cost of Coal

Note: Assumes O&M of coal-fired utility boiler exceeds gas boiler O&M by $1.00/mmBtu based on information contained in: Thermal-Electric Plant Construction Cost and Annual Production Expenses, DOE/EIA.

● - Represents actual plant; operating data (cost of gas, cost of coal, sulfur content of coal) for December, 1982. See: Cost and Quality of Fuels for Electric Utility Plants, DOE/EIA.

Select Use: A Feasible and Well-Proven Technology

A special advantage of select use is that it can be implemented quickly, with very low capital costs. One possible research project, which would reduce SO_2 emissions quickly, involves the implementation of the select use concept on an interim basis. By employing a select use sulfur oxide control strategy on an interim basis, any changes in the acidity of rain and lakes could be monitored and any cause-and-effect relationships between emissions and this acidity could be better assessed. This strategy avoids long lead times and large investments for major pollution control equipment, as well as the economic dislocations of high to low sulfur coal switching. It also preserves future SO_2 control options so that -- *if* research pinpoints acid rain sources -- flexibility is retained as to the optimum permanent course to pursue.

A.G.A. recently compiled a list of facilities that use some mixture of natural gas and another fuel. This tabulation shows that Select Use is a control strategy that we can use here and now.

Examples of Select Gas Use Applications

State	Company	Gas Used in Conjunction With
NJ	Atlantic City Electric [1]	Coal
MA	Boston Edison	Oil
RI	Narragansett Electric	Oil
PA	Andre's Greenhouse	Oil
AL	3M	Oil
CT	Uniroyal	Oil
VT	Burlington Electric	Oil
PA	U. S. Steel	Coal
PA	Scott Paper	Oil
PA	Arbogast & Bastian	Oil
PA	J. H. Thompson	Oil
PA	U. S. Steel	2/
PA	Bellefield Boilers	Coal
MO	Springfield Utilities	Coal
NJ	Public Service Electric and Gas	Coal

1/ Company operated on a 50:50 gas/coal mix from 1980 through 1982 for SO_2 control while scrubbers were being installed; no longer using gas.

2/ Natural gas used to offset SO_2 emissions from various coke ovens, soaking pits, boilers, furnaces and other steel industry operations.

Natural Gas Supplies Are Abundant: The Gas Industry Is Well Able To Satisfy The Select Use Market.

If plant operators can choose select use, as one of many options, as much as 1 Tcf/year of natural gas might ultimately be used for environmental compliance. Nationally, the natural gas industry is quite capable of supplying this market. 1 Tcf/year is only approximately 5% of current or projected yearly U.S. production. At the present time, we estimate that the U.S. has at least as 3 Tcf excess deliverability: that is, gas shut-in or not taken. A 1 Tcf investment in select use could translate into a 2 million ton/yr. SO_2 reduction. If select use were combined with coal washing, that same 1 Tcf could reduce SO2 by nearly 4 million tons/year. This strategy also reduces NO_2 and particulate emissions, as well as solid wastes.

Furthermore, future gas supplies are ample. A.G.A.'s Gas Supply Committee - which is made up of a broad spectrum of gas industry experts -- recently revised our independent supply forecast for the end of this century. The Committee considered three different policies:

- North American Self-Sufficiency, in which the nation relies entirely on lower 48 state resources, Alaskan gas, and Canadian and Mexican imports;
- High Alternative Fuel Prices, in which world crude oil prices rise somewhat rapidly, thus pushing-up gas prices; and
- Low Alternative Fuel Prices, in which world crude oil prices rise less rapdily, thus restraining gas prices.

In each and every case, gas supplies were adequate in the year 2000. The average supply estimate for the three scenarios, which appear below, is 22.4 Tcf in 2000 -- an increase of 20% over actual gas production in 1982.

TABLE I-1
GAS SUPPLY-2000
(in Tcf)

Scenarios	Self-Sufficiency	High-Price Alternative Fuels	Low-Price Alternative Fuels
Conventional Lower-48	15-16	14-15	12-13
Incremental Tight Formations	2-3	1-3	0.3-1.5
Total Lower-48	17-19	15-18	12.3-14.5
Alaska	1.4	0.9	0.8
Canada	2.4	2.4	1.5
Mexico	1.5	1.0	1.5
LNG	0.2	1.0	0.2
Coal Gas	1.5	1.0	0.3
SNG	0.1	0.1	0.2
Nonconventional	0.6	0.4	0.2
Totals	24.7-26.7	21.8-24.8	17.0-19.2

It is important to note that our revision considered the following "economic realities": (a) a slowdown in the rate of economic growth, factoring in uncertain interest rates; (b) declining U. S. demand for all forms of energy, due to conservation and increasingly efficient processes; and (c) a new slant towards conventional oil and gas supplies and away from synthetic fuels. Although these three factors may all operate to check gas supplies. the overall forecast still reveals a healthy range of gas supplies from a low of 17 Tcf to a high of 26.7 Tcf.

Summary

The benefits of multiple control strategies for SO_x reductions are many. Select Use, in particular:

- Maximizes the use of Eastern coal and minimizes the economic and social dislocations among mining communities;
- Avoids plant derating, increased solid waste, increased particulates, and railroad transportation problems associated with straight coal strategies;
- Speeds emission reductions, since new equipment or plant modifications are minimal in most cases;
- Saves the nation valuable time, since select use can be used temporarily to reduce emissions quickly while research is ongoing; and
- Reduces the high capital costs of a mandatory scrubber program.

With myriad benefits, select use is a vital alternative for the nation to consider. Now is the time to take advantage of the environmental benefits of our cleanest burning fossil fuel, a long term adequate supply of which appears very attainable. We can do that by: (1) repealing incremental pricing and the Fuel Use Act ban on gas use by powerplants and industry; (2) incorporating in proposed SO_2 reduction legislation performance standards rather than specific fuels or control strategies; and (3) directing the Environmental Protection Agency to accept select use as a viable and desirable control technology under existing provisions of the Clean Air Act.

Richard

Clean Coal Coalition, Inc.
1828 L Street, N.W.
Washington, D.C. 20036
Phone (202) 887-5537

May 8, 1984

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Honorable James A. McClure, Chairman
Committee on Energy and Natural Resources
358 Dirksen Senate Office Building
Washington, D.C. 20510

Dear Chairman McClure:

On behalf of the membership of the Clean Coal Coalition, we respectfully file and request that the enclosed statement be incorporated in the record of the hearing conducted by the Committee on April 30, 1984 on Oversight of Implementation of the Acid Precipitation Act of 1980.

The salient point of the enclosed statement is that, of the several currently available methods for reducing sulfur dioxide emissions, conventional coal cleaning is the only approach which would not impose a direct financial penalty upon the utility ratepayer, shareholder, energy user, or coal miner. Even without exploiting the residual energy in its refuse stream, coal cleaning is better than a "least-cost" measure: it is a negative cost alternative, and hence the first measure to employ in any least-cost control strategy.

The question before the Committee therefore should be not how to raise tax revenues to finance a massive program of parasitic scrubber installations but how to provide appropriate financial incentives for industry to invest in productive facilities which can minimize the need for scrubbing.

We thank you for the opportunity to file these views with your Committee, and respectfully request their fair consideration as the Committee continues oversight of the acid rain issue and related legislative proposals affecting the utilization of our most abundant domestic energy resource.

If we can provide further assistance regarding these matters, please do not hesitate to contact us further.

Yours sincerely

Leon Green Jr

Leon Green, Jr.
Vice President

Enclosures

Clean Coal Coalition, Inc.
1828 L Street, N.W.
Washington, D.C. 20036
Phone (202) 887-5537

Submitted Statement

of

Dr. Leon Green, Jr.
Clean Coal Coalition, Inc.

For the record of
the hearing before

Committee on Energy and Natural Resources
United States Senate

on

Oversight of Implementation of
the Acid Precipitation Act of 1980

April 30, 1984

The Clean Coal Coalition is an organization of interested companies dedicated to the development of government policies which favor the use of flexible, least-cost emission control strategies under the Clean Air Act, particularly for the reduction of acid rain. Companies representing a variety of viewpoints drawn from the industrial user, electric utility, gas utility, coal processor, engineering and consulting communities comprise the Coalition.

Emission Control Alternatives

The near-term options available for immediate implementation as sulfur dioxide control measures are compared in Attachment A. They are the following:

- Precombustion coal cleaning
- Fuel switching or blending
  - Low-sulfur coal
  - Natural gas
- Flue gas desulfurization (scrubbing)

Coal Cleaning and Waste Burning

Of these options only the first, conventional physical coal cleaning, is a negative cost measure. Removing the ash-forming mineral matter from coal reduces the slagging and fouling of boiler tubes, thus increasing boiler performance and availability, and thereby lowers the cost of producing steam and electricity. This fact has been demonstrated by the experience of the American Electric Power Company cited in Attachment A.

The saving is achieved despite the cost of losing a significant amount of fuel value to the refuse stream during the cleaning operation. Still largely unrecognized is another fact: this loss can be eliminated by burning the waste in a sulfur-capturing fluidized-bed combustor. Highly efficient "circulating" FBC boilers have been commercially proven in Europe and are now entering heavy industrial service in the United States.

As discussed in Attachment B, cogeneration of electric power and process heat (for drying the cleaned coal) in a facility of this type can transform coal preparation plants from operational cost sinks to sources of profit by sale of the excess power to the utility grid. Such distributed cogeneration can also relieve the utility of the need to build costly new central-station generating capacity.

Fuel Switching or Blending

Switching to low-sulfur coal has been touted by low-sulfur coal producers as the "least-cost" option for utilities despite the premium price of such coal and its vulnerability to transportation rate increases by the railroads. This spurious claim has been debunked by testimony before the Committee on April 30, 1984. Added to the cost of plant modifications, closing of mines and penalties for breaking long-term supply contracts with local coal producers would be the high but hard-to-quantify social cost of disemploying miners with its associated ripple effect on the local economy.

A form of fuel blending which would not involve significant capital cost is augmentation of the coal by "select use" of natural gas. If applied judiciously to cleaned (not raw) coal, select use of gas could bring a near-compliance coal into full compliance with an absolute emission standard (e.g., 1.2 pounds of SO_2 per million Btu). Such an application would constitute a true "least-cost compliance" strategy. The regulatory impacts and regional applicability of select use are shown in Attachment C.

Flue Gas Desulfurization

Of the three basic emission control alternatives, the scrubber option is by far the most costly. Attachments A and B cite a study by the Pennsylvania Electric Company showing that, on average, the capital cost of a flue gas desulfurization plant is $230 per kilowatt, or more than ten times the cost of a low- to midlevel physical coal cleaning plant at $20 per kilowatt. Such a comparison of apples and oranges, however, actually understates the true difference. As noted earlier, a coal-cleaning facility is a productive investment, not a "cost", since it increases the efficiency, capacity and availability of the power plant and thus reduces the cost of generating electricity. In contrast, the FGD plant is parasitic, requiring 5 to 10 percent of the power plant's output for its operation and thereby decreasing net capacity.

By the same token the comparison of operational costs in the cited Penelec study understates the case. On average, the FGD plant costs 10 mills per kilowatt hour annually to own and operate compared to 3 mills per kilowatt hour for the coal-cleaning plant. Again, it must be emphasized that the cost of operating the cleaning plant, even without exploiting the residual energy in its waste stream, is more than recovered in the improved performance of the power plant.

Conclusion

The Clean Coal Coalition therefore submits that the question before the Congress should be not how to raise tax revenues to finance a massive program of parasitic scrubber installations but how to provide appropriate financial incentives for industry to invest in productive facilities for coal cleaning and waste burning which can minimize the need for scrubbing. Such incentives are discussed in Attachment D.

The Coalition urges the Congress to remove the language in the Clean Air Act stating limits for sulfur dioxide emissions in terms of percentage reductions which effectively mandate post-combustion cleanup only and preclude more attractive, cost-beneficial alternatives. Federal statutory requirements should not operate to dictate FGD as the only emission control option, but should preserve freedom of choice for use of other, less costly emission control strategies. The individual plant operator should be entitled under the Act to determine which combination of control measures would be most effective and sensible on the basis of the site-specific characteristics of the plant.

Comparable changes would also be necessitated in the Internal Revenue Code to correct its bias favoring post-combustion cleanup options for tax incentives while effectively excluding pre-combution options for incentives offered by tax credits, rapid amortization and bond financing mechanisms in the Code.

Finally, we would focus Congressional attention on the fact that conventional coal cleaning is, and should be recognized as, the most cost-effective first step toward control of sulfur dioxide emissions which, to some degree yet unquantified, contribute to the formation of acid precipitation.

Attachment A

Public Utilities
FORTNIGHTLY

Sulfur Emission and Acid Rain: A Least-cost Approach to the Problem

By Leon Green, Jr.[*]

REPRINTED FROM
PUBLIC UTILITIES FORTNIGHTLY
ARLINGTON, VA.
1985

WHAT OTHERS THINK

Sulfur Emission and Acid Rain: A Least-cost Approach to the Problem

By Leon Green, Jr.*

This article asks – and answers – the question: What can be done most quickly, effectively, and economically within the next decade to reduce sulfur dioxide emissions from coal-burning power plants. Further research upon the various contributors to acid rain is desirable, but corrective action can no longer wait upon its findings. In the words of the White House peer review panel,[1] the acid deposition problem has reached the point where "actions have to be taken despite incomplete knowledge." This is a situation which scientists find uncomfortable but which is familiar to engineers. The very nature of engineering, as distinguished from science, is that it always must proceed on the basis of incomplete information. Research as a substitute for action is not an option.

Corrective Actions

What should these actions be? As indicated above, they must be cost effective and available for immediate implementation. Three options meet the availability criterion:

- Precombustion coal cleaning
- Switching to low-sulfur coal
- Flue gas desulfurization (scrubbing)

Which is the most cost effective? The White House review panel reasonably recommends that "the proper initial approach is to select particularly economically effective steps" and concludes that such "first, 'least-cost' steps" might include reducing sulfur emissions by intensifying coal washing."[2]

This conclusion is not surprising. Of the above options, the last two carry a cost penalty to the utilities involved (and hence to their ratepayers), whereas the first represents an investment which will benefit the utilities in terms of increased plant efficiency and availability. Moreover, the initial remedial action need not be "intensifying" conventional coal washing procedures but merely practicing them more widely.

TABLE 1
COMPARATIVE CHARACTERISTICS OF PROPOSED SULFUR DIOXIDE CONTROL MEASURES

Control Measure And Industrial Advocacy Group	*Relative Cost*	*Cost Borne by*
None pending further research (NCA, EEI, ABES)	Low	Government programs
Flue gas desulfurization (Scrubber constructors)	High	Special taxation
Switch to low-sulfur coal (ACE)	Indeterminate	Utility ratepayers, coal miners
Wider practice of coal cleaning (CCC)*	Negative over long term	Industry investment

*Augmented by waste burning using conventional technology, select use of natural gas, and introduction of deeply cleaned coal-water fuels.

ABES – Alliance for Balanced Environmental Solutions
ACE – Alliance for Clean Energy
CCC – Clean Coal Coalition
EEI – Edison Electric Institute
NCA – National Coal Association

As indicated in Table 1, the scrubber option is the most costly. A study by the Pennsylvania Electric Company has shown that on average the capital cost of a flue gas desulfurization (FGD) system is $230 per kilowatt, more than ten times the cost of low- to midlevel physical coal cleaning (PCC) systems at $20 per kilowatt. An

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*PhD, president, Energy Conversion Alternatives, Ltd., Washington, D. C., and cofounder (with Michael J. Zimmer, Esquire) in August, 1983, of the Clean Coal Coalition, Inc.

[1] "General Comments on Acid Rain," a summary by the Acid Rain Peer Review Panel for the Office of Science and Technology Policy, Executive Office of the President, June 27, 1983.

[2] W. C. Ackerman, testimony before a joint hearing on acid rain by the Subcommittees on Energy Development and Applications and on Natural Resources, Agriculture Research, and Environment of the House Committee on Science and Technology, September 13, 1983.

FGD system costs, on average, ten mills per kilowatt-hour annually to own and operate (first year costs) compared to three mills per kilowatt-hour for an PCC system.[3] A third, unstated but large, cost of FGD systems is that they lower the overall availability of the power plant. Contrary to a common but uninformed belief, scrubbers are not "mechanical devices . . . which filter out sulfur dioxide"[4] but complex chemical plants connected directly downstream of the power plant itself. Their well-known susceptibility to failure adversely affects overall system reliability and availability with an associated high-cost penalty discussed below.

Switching to imported, low-sulfur coal might be lower in direct cost to the utility despite its already premium price and vulnerability to transportation rate increases by the railroads. However, the cost of breaking long-term supply contracts with local coal producers would surely be substantial. Still higher would be the unquantifiable social cost of disemploying local coal miners. The true cost of dislocating a family cannot be measured in terms of lost wages alone, as has been disingenuously proposed,[5] with compensation paid to "retrain and help relocate" the disemployed. Retrain for what and relocate where? (Siberia, anyone?) This cavalier proposal is inviting a political fire storm.

Reward for Improved Coal Quality

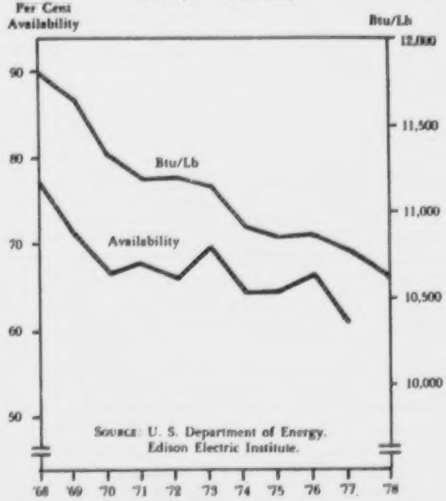
To a coal-burning utility plant, the most undesirable impurity in its fuel heretofore has not been sulfur but ash forming mineral matter which causes fouling and slagging of its boiler tubes. These impurities degrade boiler performance due to reduced gas-to-tube heat transfer (hence increased heat rate to produce a given output), shorten intervals between deslagging operations, and shorten tube life due to material attack (hence decreased boiler availability).

It has been observed repeatedly that the availability of U. S. generating stations has been deteriorating over the years with the exploitation of lower-grade coal resources, as illustrated in Figure 1. As noted by a prominent electric utility executive, "The drop is very substantial having taken into account the effect of the increasing production of low Btu Power River Basin coal."[6]

The cost to the utility of impaired plant availability is also substantial. In the case of the American Electric Power Company system cited as an example, to make up a 10 per cent loss in availability of its 1,455-megawatt-electric coal-fired generating capacity due to coal-related outages would equate to a cost in excess of $1 billion (1980) for the financing and construction of new facilities.

FIGURE 1

DECLINE IN STEAM COAL QUALITY AND AVAILABILITY OF U. S. POWER PLANTS (FROM BLACKMORE)



SOURCE: U. S. Department of Energy. Edison Electric Institute.

Conversely, a more specific case of benefit from improvement in coal quality by conventional washing has been cited for the Muskingum River station on the AEP system.[7] In this case, an investment of $18 million in upgrading the preparation facility at its Central Ohio Coal Company permitted the capacity of one of its Ohio Power Company units to be upgraded from 535 to 585 megawatts-electric. This generated an increase in capacity which, if new, would have required a capital expenditure of $55 million and an annual owning cost of $13.8 million. It also increased the plant availability by 5 per cent, yielding a benefit in pretax income of approximately $6 million per year to the utility system.

Regional Coal Characteristics

The characteristics of U. S. coal vary widely according to region, bed, coal seam, and location within a seam. The composite characteristics of raw coals by region collected and aggregated by the U. S. Bureau of Mines[8] are presented in Table 2. It may be noted that the energy content of the low-sulfur, predominantly subbituminous western coals is somewhat lower than that of the eastern bituminous coals even on a moisture-free basis. Because of the much greater moisture content of the western coals, however, their actual heating value is significantly lower than that of the eastern coals.

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[3] "Evaluation and Implementation of Coal Cleaning in an Integrated Environmental Control System," by A. A. Slovik, second American Society of Mechanical Engineers-Electric Power Research Institute-Air Pollution Control Association symposium on integrated environmental controls for coal-fired power plants, February 15-18, 1983, Denver, Colorado.

[4] "High-price Cure for Acid Rain," by P. R. Portney, *The Washington Post*, August 12, 1983.

[5] Ibid.

[6] "The Outlook for Steam Coal as Used by Electric Utilities," by G Blackmore, American Mining Congress, September 21-24, 1980, San Francisco, California.

[7] "A Discussion on Enhanced Coal Technology — Coal's Market for the '80s," by G. Blackmore, testimony before the U. S. Senate Subcommittee on Energy and Mineral Resources, Blacksburg, Virginia, August 9, 1983, Appendix A.

[8] "Sulfur Reduction Potential of the Coal of the United States," by J. A. Cavallero, M. T. Johnson, and A. W. Deurbrouck, U. S. Bureau of Mines, Report of Investigation, 8118, 1976.

TABLE 2
COMPOSITE RAW COAL CHARACTERISTICS
(Bureau of Mines, Report of Investigation, 8118, 1976)

Region	*Moisture (Per Cent)*	*Ash (Per Cent)*	*Sulfur (Per Cent) Pyritic*	*Sulfur (Per Cent) Total*	*Btu Per Pound (10³)**
Northern Appalachian	1.7	15.1	2.01	3.01	12.7
Southern Appalachian	1.8	11.0	0.37	1.04	13.3
Alabama	1.4	9.5	0.69	1.33	13.7
Eastern Midwest	4.9	14.2	2.29	3.92	12.2
Western Midwest	4.0	16.2	3.58	5.25	12.1
Western	8.5**	8.9	0.23	0.68	12.4

*Moisture-free basis.
**May increase significantly during transportation to user.

The comparable characteristics of these coals following partial de-ashing in a routine preparation operation (crushing to ⅜-inch top size and heavy-media washing at 1.60 specific gravity) are presented in Table 3. It may be noted that, in addition to ash, the mineral (pyritic) sulfur content of the coals is reduced, thus together producing a greater difference in energy content between the eastern and western coals, even on a dry basis. Since the moisture content of the lower-ranked western coal is probably increased by washing somewhat more than that of the more highly developed eastern coals, the spread in actual heating value would be increased still further. This penalty in moisture content and heating value led the Bureau of Mines investigators to conclude that "therefore, considering also the high transportation costs, extensive use of these (western) coals in eastern utility plants is doubtful."[9]

TABLE 3
COMPOSITE WASHED COAL CHARACTERISTICS
(Crushed to ⅜-inch Top Size, Cleaned at 1.60 Specific Gravity)

Region	*Moisture (Per Cent)*	*Ash (Per Cent)*	*Sulfur (Per Cent) Pyritic*	*Sulfur (Per Cent) Total*	*Btu Per Pound (10³)**
Northern Appalachian	Increased	8.0	0.85	1.86	13.8
Southern Appalachian	Increased	5.1	0.19	0.91	13.2
Alabama	Increased	5.8	0.49	1.16	14.3
Eastern Midwest	Increased	7.5	1.03	2.73	13.1
Western Midwest	Increased	8.3	1.80	3.59	13.2
Western	Increased	6.3	0.10	0.56	12.8

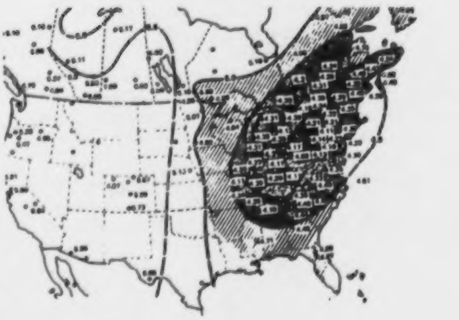
*Moisture-free basis.

Sulfur Emissions

So far nothing quantitative has been said about the potential of precombustion coal cleaning for reducing the emissions of sulfur dioxide released during combustion. Comparison of the data in Tables 2 and 3 suggest that it can be significant for those coals in which a high fraction of the sulfur content is pyritic in nature. This end result for the northern Appalachian coals is particularly fortunate, since this is the region in which acid rain is most extensive, as shown in Figure 2, which is reproduced from the National Academy of Sciences-National Research Council report "Acid Deposition."[10]

FIGURE 2

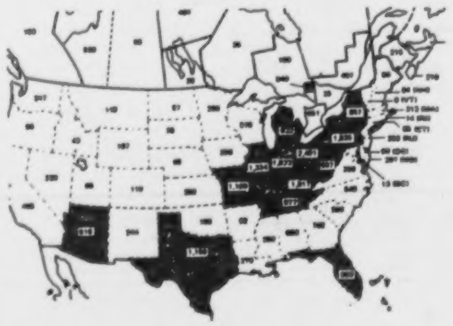
ANNUAL MEAN pH IN PRECIPITATION IN
U. S. AND CANADA FOR 1980



The corresponding sulfur dioxide emission levels in the same regions are shown in Figure 3. It may be seen that, in addition to the states in the northern Appalachian region (Ohio, Pennsylvania, northern West Virginia), New York is also a significant sulfur dioxide emitter. New York imports its coal, more than 80 per cent of it from Pennsylvania with an average heat value of 12,045 Btu per pound and average sulfur and ash contents of 1.9 and 14.3 weight per cent, respectively.[11] Because of their high sulfur dioxide emissions and close proximity upwind of the New England states most affected by acid rain, these four states constitute a regional group offering the best opportunity for a concen-

FIGURE 3

REPRESENTATIVE VALUES OF SO_2 EMISSIONS
IN U. S. AND CANADA IN 1980
(Thousands of Tonnes)



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[9] Ibid, p. 22.

[10] "Acid Deposition: Atmospheric Processes in Eastern North America," National Academy Press, Washington, D. C., 1983, p. 14.

[11] "Cost and Quality of Fuels for Electric Utility Plants, 1981 Annual," U. S. Department of Energy, DOE-EIA-0191(81), p. 72.

trated definitive experiment to determine the contribution of sulfur dioxide emissions to acid precipitation

It has been reported that the Environmental Protection Agency has deferred decision to implement a "four-states test" of the effect of reducing sulfur dioxide emissions (in Ohio, Pennsylvania, northern West Virginia, and New York) upon acid precipitation in the New England region immediately downwind because of political predictions of perceived unfairness to the utility ratepayers of those states if the cost of the experiment were borne locally. It has been pointed out earlier, however, that coal cleaning is not a net cost but an investment leading to increased plant capacity and availability. If the AEP example cited earlier is any indicator, exercise of the coal cleaning option can only improve the "bottom line" of the utilities involved.

Adding to this operational benefit accruing from coal cleaning can be the direct profit derived from burning the coal cleaning waste to recover energy value which otherwise is now lost in conventional practice. Elimination of this loss by deployment of commercially available fluid-bed combustor technology will be discussed briefly below. Furthermore, coal cleaning does not preclude additional control measures such as select use of natural gas for clean Btu augmentation or, as a last resort, scrubbing to the degree required.

Considering the above range of options, it is clear that to mandate one or another is neither desirable nor necessary. Given freedom of choice, the individual plant manager will determine the least-cost combination specific to his own requirements, and will start with coal cleaning.

Limitations of Coal Cleaning

Why has the potential of physical coal cleaning not previously received such high-level recognition? Physical methods for removing mineral impurities are effective on pyritic sulfur but do not affect the organic component, as may be concluded from comparing Tables 2 and 3. Depending upon the coal, accordingly, conventional cleaning can remove from 20 to 50 per cent of the total sulfur, whereas a wet-sludge FGD system (when operating well) can remove up to 90 per cent.[12] This leads scrubber proponents to demand "Why not the best?" and the Clean Air Act to invoke superlative requirements for "best available control technology" and "lowest achievable emission rate" without explicitly calling for consideration of the costs involved.

Judged from a benefit-cost perspective by the Environmental Protection Agency, however, coal cleaning has in fact received high marks. But, they were reported to a limited audience. First considered as an adjunct to improve the effectiveness of FGD systems,[13] PCC later received the ultimate accolade: "Physical coal cleaning is the least-cost method of reducing sulfur emissions from the combustion of coal."[14] This led the present author to coin the term "least-cost compliance" for an investment strategy combining PCC with select use of natural gas.[15]

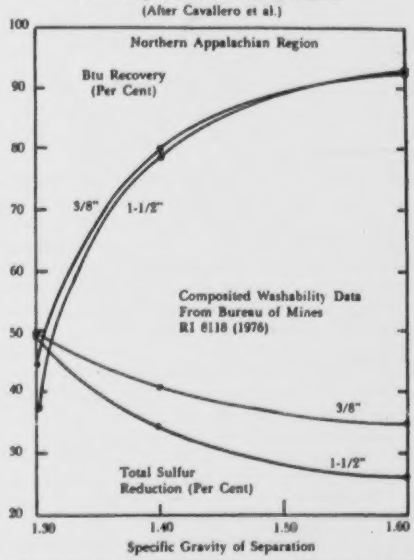
Potential of Coal Cleaning

Studies for the Environmental Protection Agency indicated that conventional washing of all the utility coal delivered in 1979 from eight states comprising four Bureau of Mines regions could have achieved an additional reduction in sulfur dioxide emissions of 2.8 million tons above that actually realized that year by cleaning only part of the coal.[16] Subsequently, this appraisal was revised downward to 2.4 million tons,[17] but a more recent review adjusted the figure upward to about 2.5 million tons and extended the analysis to indicate that somewhat more intensive cleaning could double the number to 5 million tons annually.[18]

FIGURE 4

SULFUR REDUCTION POTENTIAL OF NORTHERN APPALACHIAN COALS SUBJECT TO CONVENTIONAL WASHING

(After Cavallero et al.)



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[12] See Footnote 8.

[13] "Coal Cleaning with Scrubbing for Sulfur Control: An Engineering/Economic Summary," by E. C. Holt, Jr., and A. W. Deurbrouck, EPA-600/9-77-017, August, 1977.

[14] "Use of Coal Cleaning for Compliance with SO_2 Emission Regulations," by E. H. Hall, A. W. Lemmon, Jr., G. L. Robinson, F. K. Goodman, J. H. McCreery, R. E. Thomas, and P. A. Smith, EPA-600/57-81-146, October, 1981.

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[16] "Coal Resources and Sulfur Emission Regulations: A Summary of Eight Eastern and Midwestern States," by R. A. Chapman and M. A. Wells, EPA-600/7-81-066, May, 1981.

[17] "Coal-Preparation for Sulfur Dioxide Control: The Technology," by J. B. Strauss, statement before the Subcommittee on Health and the Environment, House Committee on Energy and Commerce, October 20, 1981.

[18] J. B. Strauss, unpublished communication, September 1, 1983.

TABLE 4

ADDITIONAL SO_2 REDUCTION ACHIEVABLE IN 1979 BY CLEANING ALL CLEANABLE UTILITY COAL IN FOUR REGIONS

Coal Source (Bureau Mines Region)	*Reduction by Conventional[1] Cleaning (10^3 Tons)*	*Average Annualized Cost of Cleaning[3] (Dollars Per Clean Ton)*	*Reduction by More Intensive[2] Cleaning (10^3 Tons)*	*Approximate Increase Over Conventional (Dollars Per Clean Ton)*
Northern Appalachia	1,420	7.5	2,860	12.27
Eastern Midwest	910	5.10	1,460	8.47
Southern Appalachia	150	7.65	530	9.65
Alabama	65	6.70	160	11.00
Total or Average	2,545	6.74	5,010	10.34

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[1] Conventional Cleaning: Crush to 1½-inch top size; separate at 1.60 specific gravity.
[2] More Intensive Cleaning: Crush to ⅜-inch top size; separate at 1.30 specific gravity.
[3] Analytical Approximation:

$$\text{Cost of Cleaning} = \text{Operational Cost} + \frac{\text{Spot Price of Coal}}{\text{Yield}}(1 - \text{Yield}).$$

NOTE: Cost of waste disposal *not* included.

These data are summarized in Table 4 together with the estimated cost of the two degrees of cleaning evaluated: conventional cleaning in which the coal is crushed to a top size of 1½ inches and separated from the mineral matter in a heavy medium (a suspension of fine magnetite in water) with a specific gravity of 1.60; and a more intensive cleaning involving crushing to ⅜-inch top size and separating at a lower specific gravity of 1.30.

It may be seen that the major additional sulfur dioxide reduction is achieved in the northern Appalachian region whose coals are the most amenable to sulfur removal by physical means, as noted earlier. It may also be seen that the additional sulfur dioxide reduction achievable by the more intensive cleaning is accompanied by a greatly increased cost of cleaning due to reduced "yield," or increased loss of energy value to the waste stream. This loss is illustrated graphically in Figure 4, which indicates that the decreased recovery (yield) is due not so much to the increased degree of comminution (size reduction) as to an excessively low specific gravity of separation. A more nearly optimum separation might appear to be at 1.40 specific gravity, yielding an 80 per cent Btu recovery and a sulfur reduction of 41 per cent. For comparison with the data of Table 4, such a degree of cleaning would produce an additional sulfur dioxide reduction of about 3.5 million tons.

Elimination of Loss to Waste

A loss of 20 per cent of coal energy value to the waste stream would be economically unacceptable to a commercial coal cleaning operation. Such a loss can be eliminated, however, if the waste is burned in a sulfur dioxide capturing fluidized bed. A plant of this type could be designed to cogenerate high-temperature process heat for drying the washed coal, electric power to drive the mechanical operations at the preparation plant and for sale to the utility grid, and benign solid combustion residue which need not be treated as a hazardous material but has useful commercial value.[19] This subject is beyond the scope of the present discussion but has been elaborated elsewhere.[20] The combustor technology required is commercially proven and available for immediate deployment.[21] The problems impeding implementation of this option are institutional in nature and should be addressed by the legislative, regulatory, and financial communities.

Conclusion

This article has pointed out that, if the utilities involved choose to exercise the least-cost sulfur dioxide control option available — namely, more widely practiced conventional precombustion coal cleaning — they and their ratepayers will benefit as a result of the experiment. These benefits can be increased by burning the cleaning waste so produced to cogenerate power, process heat, and useful solid materials. Sulfur emissions can be further reduced by augmenting the cleaned coal with natural gas. The details of such "select use" of gas are beyond the scope of the present discussion but have been elaborated at length elsewhere.[22]

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[19] "Cogeneration the Key to Effective Coal Cleaning," by L. Green, Jr., *Cogeneration World*, Vol. 2, No. 1, January-February, 1983, pp. 23, 24.

[20] "Value Derivable from Coal Waste by Entrained-flow Combustion," by L. Green, Jr., proceedings at fifth annual symposium on industrial coal utilization, June 6, 7, 1983, Pittsburgh, Pennsylvania, pp. 138-151; and "Drying Cleaned Coal by Burning Coal Waste," by L. Green, Jr., third international conference on cogeneration, October 13, 14, 1983, Houston, Texas.

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Attachment B

**First International Conference on Acid Rain
March 27 - 28, 1984, Washington, D.C.**

COAL CLEANING: THE FIRST STEP

Leon Green, Jr.

BENEFITS AND COSTS OF CONVENTIONAL COAL CLEANING

The interest of this conference in physical coal cleaning (or preparation, beneficiation, washing) concerns its potential for sulfur removal, but that is not the reason most coal is cleaned today. The original motivation for preparing coal was to lower the cost of its transportation by removing inert mineral matter. The washed coal also exhibits improved quality and uniformity in both size and Btu content, thus easing downstream fuel operations at the power plant. More recently recognized is the fact that removing the ash-forming mineral matter reduces slagging and fouling of the boiler tubes, thus increasing boiler performance and availability, and thereby lowers the cost of producing steam and electricity (1,2).

General acceptance of the fact that "The cheapest electricity is not of necessity produced from the cheapest coal" (1) has been slow, due in large part to institutional barriers inhibiting investment in preparation facilities (2). Nevertheless, all utilities are now seeking to increase the capacity and extend

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the operating life of existing plants, and are balancing the above-mentioned economic benefits from using cleaned coal against the cost of the cleaning operation itself. The assessment that "The critical economic point in the coal energy system (see Figure 1) is the wash plant" (1) is not an overstatement.

Of the operational cost components involved, the largest is the loss of Btu value to the refuse stream, a factor which limits the "depth" of cleaning economically practical. Another significant factor is the electric power required to drive the many mechanical operations involved in a preparation plant, which have been well described in a recent review by Power magazine (2). A third factor now receiving increasing attention is disposal of the cleaning refuse, which constitutes a semi-hazardous waste, in an environmentally acceptable manner.

POTENTIAL FOR SULFUR REMOVAL

Coal cleaning or preparation methods in commercial use today are physical operations based upon differences in density or in surface characteristics between coal and its mineral impurities. Most of these methods are density-based operations in which separation of maceral from mineral matter is effected by gravitational and inertial body forces acting upon the particles in aqueous media. The degree to which the impurities can be removed is a strong function of the degree of size reduction or comminution employed (3). The more finely the coal is crushed, the more mineral matter is released as discrete particles which can be removed by physical methods, but at an increased cost in terms of greater grinding power requirements and loss of fuel value to waste.

As indicated in Figure 2, the range of applications of density-based methods extends from inch-size pieces down to particle sizes of the order of 100 mesh, or about 150 microns in diameter (4). Because the specific gravity of mineral sulfur (iron pyrite) is high, of the order of 5.0 vs 1.2 to 1.7 for coal, density-based methods are effective in separating pyritic sulfur. For finer particles, separation methods based upon surface forces (e.g., froth flotation) are employed.

The potential of conventional coal-cleaning methods for removing sulfur from coal thus depends upon the fraction of the coal's sulfur content which is pyritic in nature rather than chemically-bound organic sulfur. The characteristics of U.S. coals vary widely according to region, bed, coal seam and location within a seam. The composite characteristics of raw coals by region collected and aggregated by the U.S. Bureau of

Mines (3) are presented in Table 1. It may be noted that the pyritic fraction of the total sulfur in Northern Appalachian coals is significantly higher than in coals from other regions. Such coals are thus particularly amenable to sulfur reduction by conventional washing procedures. This is a fortunate circumstance from the viewpoint of acid rain mitigation, as will be discussed below.

POTENTIAL FOR REDUCING SULFUR EMISSIONS

With the growth of concern over acid precipitation, to which the emissions of sulfur dioxide from coal-burning power plants contribute to some significant if yet unquantified degree, the original economic motivations for physical coal cleaning (PCC) have been overshadowed by an environmental priority. The previous "side benefit" of PCC in removing sulfur has become a primary motivation, and should now be legally recognized as such by investment credits to coal producers and processors as well as users installing such facilities.

Because its effectiveness is limited to pyritic sulfur removal, the contribution which physical coal cleaning can make to reducing SO_2 emissions has been dismissed by advocates of maximum environmental purity (for a variety of self-interests) demanding "Best Available Control Technology" and other superlative control requirements imposed by the Clean Air Act without consideration of the cost involved. Judged from a benefit/cost perspective by the Environmental Protection Agency, however, coal cleaning has in fact received high marks. First considered as an adjunct to improve the effectiveness of flue gas desulfurization (FGD) systems (5), PCC later received the ultimate accolade: "Physical coal cleaning is the least-cost method of reducing sulfur emissions from the combustion of coal" (6).

This judgment was confirmed in a more recent study by the Pennsylvania Electric Company which showed that "on average the capital cost of an FGD system is $230/KW, more than ten times the cost of low to mid-level PCC (physical coal cleaning) systems at $20/KW. An FGD system costs, on average, 10 mills/KWH annually to own and operate (first year costs) compared to 3.0 mills/KWH for a PCC system" (7). A third, usually unstated but large, cost of FGD systems is that they lower the net output and overall availability of the power plant. Considering these findings, it is hardly surprising that the Acid Rain Peer Review Panel of the White House Office of Science and Technology Policy singled out "intensifying coal washing" as one of the "first, 'least-cost' steps" to reduce

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sulfur emissions (8, 9). The present Administration should promote this risk-free measure to its own best interest.

The unrealized potential of conventional coal cleaning can be appreciated from the fact that only a fraction of the steam coal consumed yearly is cleaned, and generally only to a small degree (2). Studies for the Environmental Protection Agency indicated that conventional washing of all the utility coal delivered in 1979 from eight states comprising four eastern Bureau of Mines regions in the eastern U.S. could have achieved an additional reduction in SO_2 emissions of 2.8 million tons above that actually realized that year by cleaning only part of the coal (10). Subsequently, this appraisal was revised downward to 2.4 million tons (11), but a more recent review adjusted the figure upward to about 2.5 million tons (12), as indicated in Table 2.

It should be understood that this estimate is based upon conventional cleaning in which the coal is crushed to a top size of 1½-inches and separated from the mineral matter in a heavy medium (a suspension of fine magnetite in water) with a specific gravity of 1.60. A more intensive cleaning involving crushing to 3/8-inch top size and separating at a specific gravity of 1.40 would raise the estimated SO_2 reduction to about 3.5

million tons, but at an increased cost due to loss of about 20 percent of the Btu value to waste.

It was noted earlier that the Northern Appalachian coals are the most amenable of U.S. coals to cleaning by density-based separation methods. The full application of such methods is perhaps best exemplified by the preparation plant at the Homer City, Pennsylvania generating station co-owned by the Pennsylvania Electric Company and the New York State Electric and Gas Company (13). The nominal production specifications for this plant, which is pushing the state of the art in separation of fine (down to 100 mesh) coal and refuse in heavy-medium cyclones, are presented in Table 3. Its output consists of three streams: a low-sulfur stream of compliance coal (1.2 lb SO_2 per million Btu), a "middlings" stream capable of meeting Pennsylvania emission regulation for large plants existing prior to 1977, and a high-sulfur, high-ash refuse stream.

OFFSETTING THE COST OF CLEANING

The Homer City plant exemplifies the highest of the six recognized levels of coal preparation, a level known alternatively as Level F, multistream cleaning, deep cleaning or full beneficiation (2) which involves considerable investment in equipment for recovery of coal fines. Thermal drying of the fines to remove surface moisture constitutes another cost factor not only in capital equipment but in burning some of the cleaned product for process heat. Except for the environmental requirements of a co-located power station, such "cleaning down to zero" would not be economically justified (14), especially not to independent coal producers with no market for their fines, however clean. Loss of fines to waste, on the other hand, is also unprofitable.

Nevertheless, wider application of deep cleaning, particularly of Northern Appalachian coals burned in the four states (New York, Ohio, Pennsylvania, and northern West Virginia) immediately upwind of the Adirondack area where acid precipitation is most severe, could effect reductions in SO_2 emissions much greater than those achievable by the cursory washing on which the estimates of Table 2 were based. It has been estimated that vast reserves of washable coal exist in that region, 10 billion tons in central Pennsylvania alone (13).

It is therefore important to recognize that the various costs of coal cleaning mentioned above can be more than offset by burning the cleaning waste to cogenerate electric power, process heat for drying and a benign combustion residue using

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proven, commercially available fluid-bed combustion technology (15). As diagrammed schematically in Figure 3, such a waste-burning facility could provide power and heat to the preparation plant, sell its excess power to the utility grid and produce a benign solid residue with commercial value (16).

SPECIAL COMBUSTION REQUIREMENTS

The solid combustion residue deserves special attention not only because its quantity is large but because it represents the culmination of a process whereby a noxious waste is converted into a useful product. Whether accumulated in waste ponds or "gob" piles or disposed by more careful burial in land-fill operations, raw coal refuse constitutes not only a potential source of acid drainage but a repository of minerals containing water-soluble compounds of trace elements such as heavy metals, leaching of which must be contained. Elimination of these potential hazards is essential if the combustion residue is to find very large scale applications such as agriculture and soil conditioning. This stringent environmental condition imposes a special requirement upon the waste combustion process: it must consume the residual coal virtually completely and fully oxidize the trace metals to a state of negligibly low solubility (17). Once immobilized, such elements cannot enter the food chain.

Two other combustion requirements are imposed by the nature of the coal tailings. Because of the high fines content of such refuse the waste combustor must be able to burn fines efficiently. Because of the high sulfur content, a large surface area of sulfur-capturing sorbent material (limestone or dolomite) is required to assure adequate control of SO_2 emissions.

The requirements mentioned above, plus that of ready commercial availability in high-capacity units, constrain the choice of combustion technology applicable for waste burning to the entrained-flow or "circulating fluid bed" combustor (CFBC) which has come to dominate the heavy industrial market (17). Since all fluid-bed combustors employ some degree of fines recycle, as indicated schematically in Figure 4, it is important to distinguish the CFBC, the "rapidly circulating" system depicted as Unit C of that figure, from the obsolescent "bubbling" FBC design which the U.S. Department of Energy has been trying to promote (Unit A) and the "slowly circulating" FBC (Unit B) into which the bubbling bed has evolved under a program sponsored by the Tennessee Valley Authority. By virtue of the

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high specific surface of its fine sorbent particles (the order of 100 microns diameter vs 2 or 3 mm for the slowly recycling systems) and its high (99+ percent) demonstrated combustion efficiency, the CFBC alone meets the requirements stated above.

Although the diagram of Figure 3 indicates a cogenerating CFBC installation, such units can be designed to produce only electric power or process heat alone, depending upon the needs of the preparation plant. For example, Figure 5 shows the preliminary design of a CFBC unit for burning the washing waste from a metallurgical coal mine to operate an 80-million Btu per hour coal dryer (18). However, it is expected that most waste-burning installations will also generate electric power. The waste stream from the Homer City preparation plant, for instance, contains enough energy to generate nearly 100 MWe if desired. Distributed power generation by multiple plants of this size (19) could permit retirement of a few of the oldest and "dirtiest" central-station generators, relieve utilities of the need for large increments of capital outlay for new central generating capacity (20), and, by virtue of redundancy, improve system reliability.

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ADVANCES IN COAL CLEANING

As indicated in Figure 2, purely density-based separation methods become ineffective for coal particles finer than 100 mesh (about 150 microns) and flotation methods based upon differences in surface characteristics are employed. At least one coal producer offers fines cleaned by froth flotation, but this procedure truly approximates "cleaning down to zero" and from the viewpoint of most producers it is not economically practical to employ such methods.

The lower limit of particle size economically cleanable using density-based methods is expected to be determined by results forthcoming from the Electric Power Research Institute's new Coal Cleaning Test Facility at Homer City, Pennsylvania (21) which is expressly designed with flexibility to optimize a system of aqueous separation methods so as best to clean any given producer's particular coal. This author expects that the density-based methods optimized by the CCTF will become the standard of the coal producing industry, and that methods employing surface forces for still finer cleaning will be practiced primarily by a newly emerging "coal refining" industry producing very deeply-cleaned coal-water mixture (CWM) fuels as a substitute for residual fuel oil in industrial and utility boilers (21).

If the Penelec/NYSEG multistream prep plant represents "deep" cleaning in current preparation parlance (2), processing of CWM fuels involves "deep deep" cleaning to reduce the ash content to a level of the order of one percent. Such a high degree of physical cleaning also substantially removes the pyritic sulfur, leaving essentially only the organic. In the case of readily "washable" coals this procedure produces a compliance or near-compliance fuel (22).

The fine particle-size distribution employed by CWM fuels not only stretches the art of physical coal cleaning to its limit but facilitates an economical means of removing organic sulfur as well. Chemical methods for removing chemically-bound organic sulfur have been investigated and found wanting. Not only are the high-temperature processes involved too costly for commercial application, but they drive off the volatile components of the coal which are desirable for stable combustion.

Much more promising is a microbial process which proceeds in aqueous media at ambient temperature. The action of the genetically engineered micro organism involved converts the

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organic sulfur compounds to water-soluble products which can be removed from the coal particles by standard washing procedures. The Btu value and the volatile content of the coal are not significantly altered by the microbial treatment (23).

The ambient-temperature, microbial process has the advantage of low capital and operational cost. The process is being scaled up in a pilot facility capable of treating 1000 pounds of coal per day. If commercialization of this process is successful, it will open up the prospect for full utilization of our vast resources of high-sulfur Midwestern coal without involving costly scrubbers and their attendant waste disposal problems. Should this happy development come to pass, coal cleaning will constitute not only the first step toward control of acid rain, but the conclusive step as well.

CONCLUSION

This paper has pointed out the capability of existing commercial technologies for the cleaning of coal in aqueous physical operations and for burning the refuse in sulfur-capturing fluid-bed combustors to improve the economics of electric power generation while significantly reducing the emissions of SO_2 thereby produced. Considering the ready availability of these mature technologies for immediate application, the Clean Coal Coalition rejects the premise stated by the organizers of this conference that "acid rain emission control will cost American industry, particularly the electric utility industry, billions of dollars."

This prophecy, which seemingly is intended to become self-fulfilling by inviting precipitous Congressional action mandating massive and arbitrary levels of SO_2 reductions to be achieved primarily by flue gas scrubbing, is false. It is not inevitable and can be averted by recognition by the public and, especially, by its legislators of the productive (not parasitic) alternative technologies mentioned above. Advancement of such recognition is the raison d'etre of the Coalition.

Notes:

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Notes:

TABLE 1
Composite Raw Coal Characteristics
(Bureau of Mines, Report of Investigation 8118, 1976)

Region	Moisture (Per Cent)	Ash (Per Cent)	Sulfur Pyritic	(Per Cent) Total	Btu Per Pound (10^3)*
Northern Appalachian	1.7	15.1	2.01	3.01	12.7
Southern Appalachian	1.8	11.0	0.37	1.04	13.3
Alabama	1.4	9.5	0.69	1.33	13.7
Eastern Midwest	4.9	14.2	2.29	3.92	12.2
Western Midwest	4.0	16.2	3.58	5.25	12.1
Western	8.5**	8.9	0.23	0.68	12.4

*Moisture-free basis.

**May increase significantly during transportation to user.

TABLE 2
Additional SO_2 Reduction Achievable in 1979 by Cleaning All Cleanable Utility Coal in Four Regions

Coal Source (Bureau Mines Region)	Reduction by Conventional* Cleaning (10^3 Tons)	Average Annualized Cost of Cleaning (Dollars Per Clean Ton)
Northern Appalachia	1,420	7.5
Eastern Midwest	910	5.10
Southern Appalachia	150	7.63
Alabama	65	6.70
Total or Average	2,545	6.74

*Conventional Cleaning: Crush to 1½-inch top size; separate at 1.60 specific gravity.

Note: Cost of waste disposal *not* included.

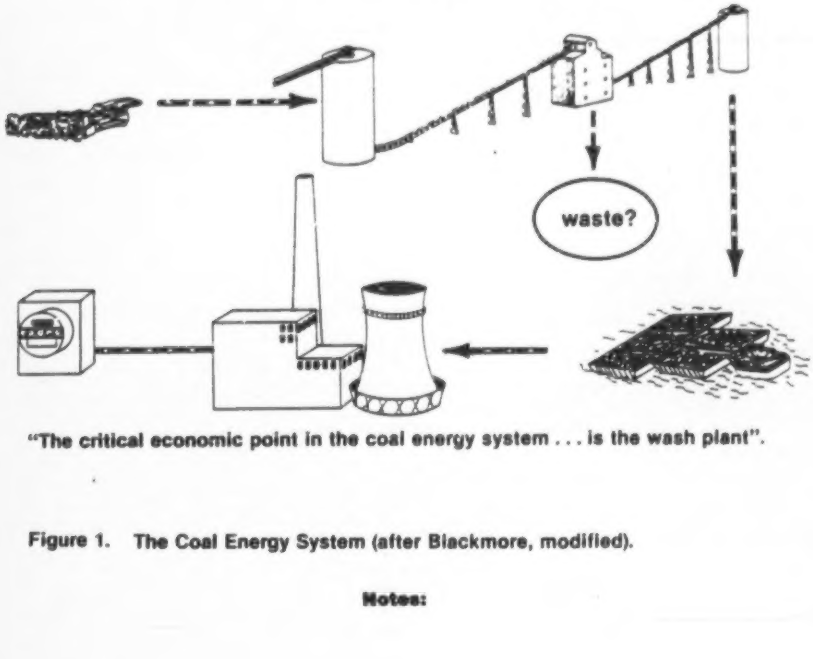
Notes:

TABLE 3
Homer City Plant Production Specifications

Item	Medium sulfur coal	Low sulfur coal	Refuse
Weight distribution (percent)	56.2	24.7	19.1
Energy distribution (percent)[a]	61.6	32.9	5.5
Energy content (Btu/lb dry basis)	12,500	15,200	3,400
Ash content (percent)	17.75	2.84	69.69
Sulfur content (percent)	2.24	0.88	6.15
SO_2 emission factor (lb/10^6 Btu)	3.6	1.2	65.9

[a] Overall plant Btu recovery is 94.5 percent, which includes 1 percent credit for thermal drying loss.

Notes:



The Coal Energy System

"The critical economic point in the coal energy system . . . is the wash plant".

Figure 1. The Coal Energy System (after Blackmore, modified).

Notes:

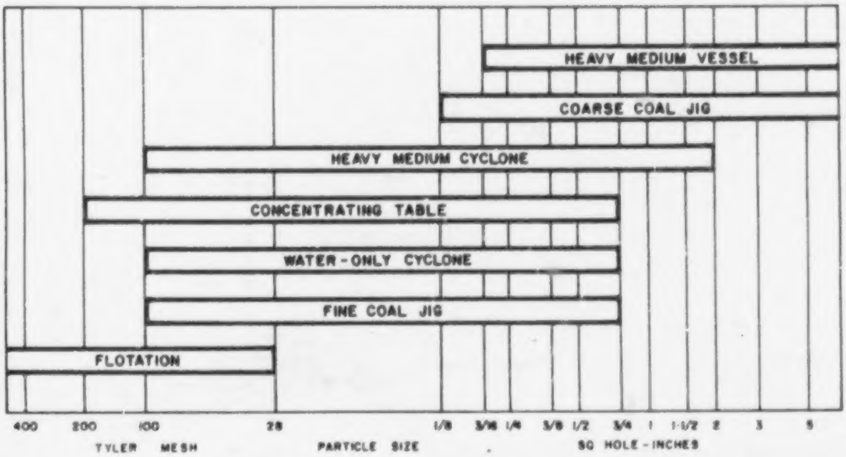


Figure 2. Range of Application for Major Coal Cleaning Devices (from Terry).

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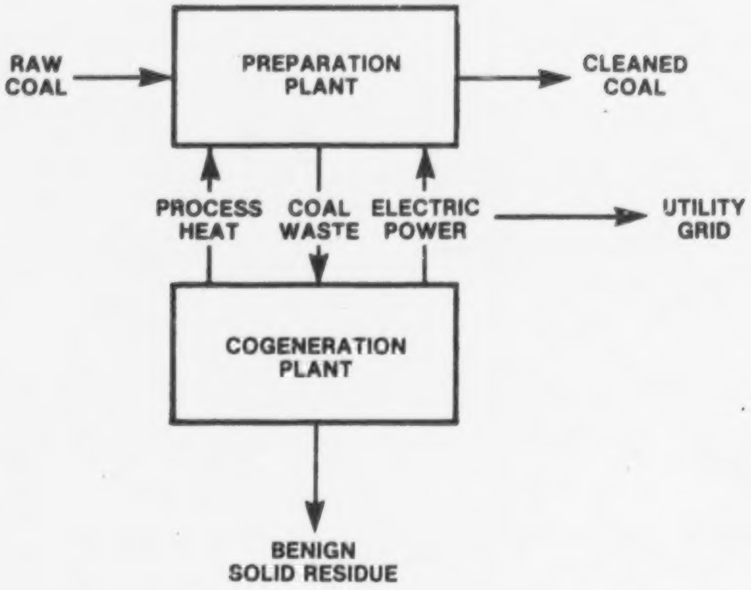

RAW COAL
PREPARATION PLANT
CLEANED COAL
PROCESS HEAT
COAL WASTE
ELECTRIC POWER
UTILITY GRID
COGENERATION PLANT
BENIGN SOLID RESIDUE

Figure 3. Schematic Block Diagram of a Fluid-Bed Cogeneration Plant Operating on Preparation-Plant Waste.

Notes:

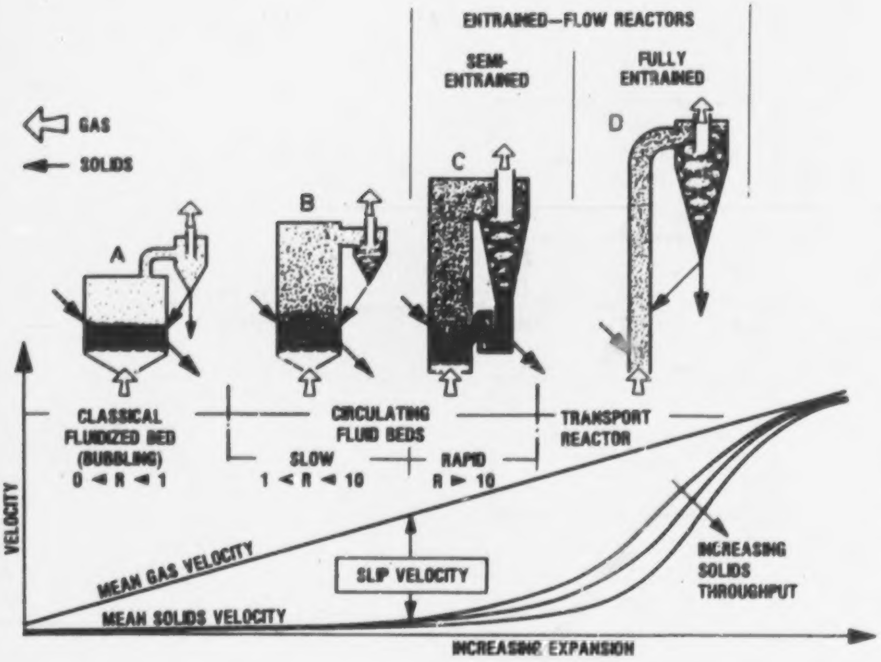

ENTRAINED—FLOW REACTORS
SEMI-ENTRAINED
FULLY ENTRAINED
GAS
SOLIDS
A
B
C
D
CLASSICAL FLUIDIZED BED (BUBBLING)
0 < R < 1
CIRCULATING FLUID BEDS
SLOW
1 < R < 10
RAPID
R > 10
TRANSPORT REACTOR
VELOCITY
MEAN GAS VELOCITY
SLIP VELOCITY
MEAN SOLIDS VELOCITY
INCREASING SOLIDS THROUGHPUT
INCREASING EXPANSION

Figure 4. Different Types of Fluidized-Bed Reactors with Different Regimes of Particle Slip Velocity and Solids Recycle.

Notes:

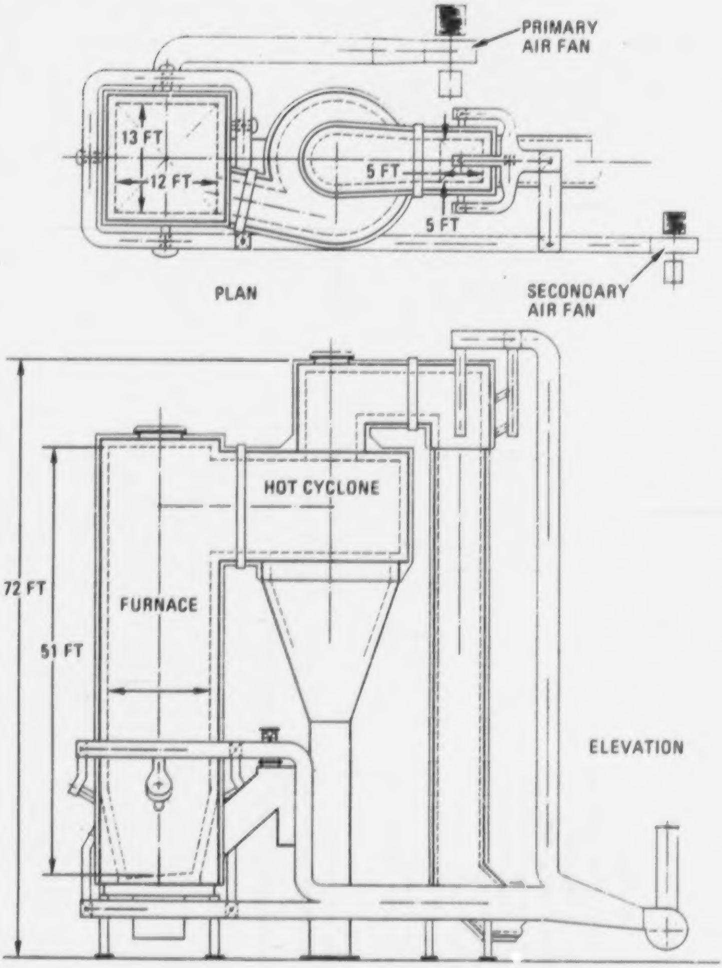

PRIMARY AIR FAN
13 FT
12 FT
5 FT
5 FT
PLAN
SECONDARY AIR FAN
HOT CYCLONE
FURNACE
72 FT
51 FT
ELEVATION

Figure 5. 80 MMBtu/hr CFBC Hot Gas Generator.

Notes:

Attachment C

Source: Evaluation of the Environmental and Other Benefits of the Select Use of Natural Gas, Environmental Research & Technology , Inc., Washington, D.C. (November, 1983)

1.

REGULATORY IMPACTS ON THE POTENTIAL FOR SELECT GAS USE

Market	Impact of Clean Air Act	Impact of Fuel Use Act	Combined Impact
Existing Electric Powerplant	●	●	●
Existing Large Boiler	●	●	●
Existing Small Boiler	●	●	●
Existing Large Non-Boiler	●	●	●
Existing Small Non-Boiler	●	●	●
New Small Boiler	◒	●	◒
New Small Non-Boiler	△	●	△
New Large Non-Boiler	▲	●	▲
New Large Boiler	▲	△	▲
New Electric Powerplant	▲	△	▲

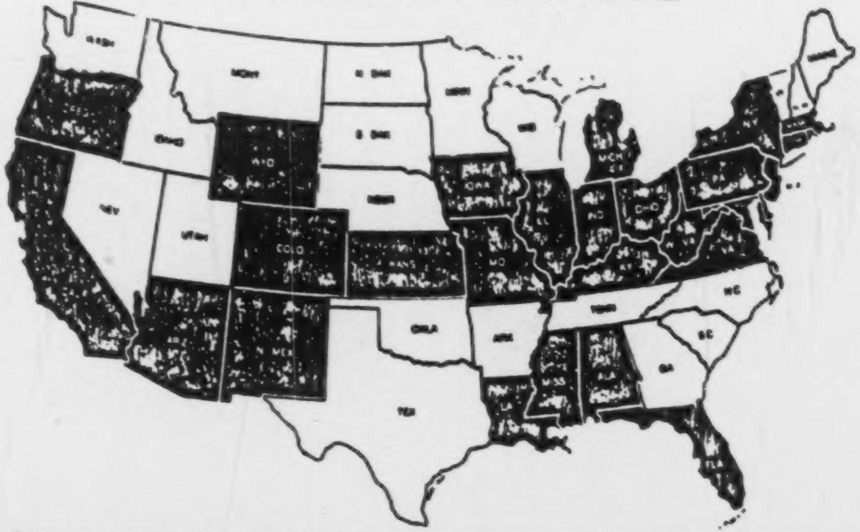
Legend

● Not a Constraint
◒ Moderate Constraint, Sizable Market
△ Moderate Constraint, Limited Market
▲ Severe Constraint

Note: Judgment Based on Current Interpretation of Legislation

2.

STATES WITH HIGH POTENTIAL FOR SELECT GAS USE


WASH
MONT
N DAK
MINN
MAINE
IDAHO
S DAK
WIS
WYO
MICH
NY
NEBR
IOWA
PA
NEV
UTAH
COLO
KANS
ILL
IND
OHIO
MO
KY
W VA
VA
NC
TENN
OKLA
ARK
SC
ARIZ
N MEX
GA
MISS
ALA
LA
TEX
FLA

Note: States shaded have relatively strict sulfur emission limits (oil <1 #/MMBtu; coal < 1.2 #/MMBtu) and also have either a heavy dependence on oil for electrical generation (> 10%), or have powerplants which are not currently meeting their sulfur emission limit.

Attachment D

Clean Coal Coalition, Inc.
1828 L Street, N.W.
Washington, D.C. 20036
Phone (202) 887-5537

January 13, 1984

FEDERAL TAX ISSUES AFFECT DEPLOYMENT OF COAL CLEANING TECHNOLOGY OPTIONS*

Pre-combustion coal cleaning and preparation techniques are in the forefront of developing alternative energy and environmental technologies. Unfortunately, federal income tax law, and particularly Federal income tax incentive programs, have generally not kept pace with technology developments in this area. This analysis attempts to summarize major Federal income tax incentive programs as they pertain to coal cleaning technologies, and offer recommendations on approaches under which incentives might be provided for such technologies in the future.

PRESENT TAX PROGRAMS

Rapid Amortization

The only incentive for coal cleaning equipment which is presently available in the Internal Revenue Code (Code) is rapid amortization of the costs of the cleaning equipment. However, while this once could have been a significant incentive, the inherent limitations on the scope of this provision, coupled with subsequent developments before the Congress, have significantly reduced its usefulness to the taxpayer.

Rapid amortization allows a taxpayer to recover the cost of qualifying equipment ratably over a 5-year period. When it was enacted, this approach provided a significant incentive because it allowed cost recovery over a much shorter time period than was available under depreciation practices available at that time. However, with the enactment of the Accelerated Cost Recovery System (ACRS) in 1981, most business property can be depreciated over a 5 year period, and at accelerated rates. Accordingly, rapid amortization is now only a meaningful incentive for public utility property, for which ACRS provided a 10 or 15-year recovery period.

Rapid amortization is available for pollution control equipment, including equipment which prevents the creation of pollution, which is installed pursuant to a state pollution control program, and which satisfies certain federal requirements. There are several significant limitations on the scope of this provision:

1) The equipment must be installed in connection with a facility which was in operation on January 1, 1976.
2) The equipment must not increase the output of the facility, alter the nature of the production process at the facility, or perform a function in addition to controlling pollution.

3) The equipment must not have a useful life in excess of 15 years. If it does, the portion of the cost subject to amortization may have to be reduced.

Unlike most items of amortized property, pollution control equipment is eligible for the full investment credit. */ However, the election of rapid amortization may increase the taxpayer's minimum or alternative minimum tax liability exposure. Finally, for certain corporations, rapid amortization may only be claimed with respect to 85% of the amortizable basis of the property.

Industrial Development Bonds

Tax-exempt financing through the use of tax-free industrial development bonds has became a popular source of debt financing for a variety of private sector projects. Tax-exempt financing can generally be used only for investments in one of the specific categories of "exempt facilities" listed in the Code, such as air pollution control facilities. Unfortunately, the IRS has consistently taken the position that, for purposes of Section 103, pollution control equipment does not include equipment which removes potential pollutants from a fuel or feedstock. Instead, the property must be used to remove, alter, or dispose of a pollutant once it has been produced. See Proposed Reg. § 1.103-8(g)(2)(ii). Accordingly, pre-combustion coal cleaning equipment would not be eligible for IDB financing because of this restriction.

Energy Tax Credits

The Energy Tax Act of 1978 provided an energy tax credit for certain items of energy property, including "alternative energy property." The alternative energy property category included several classes of property which utilize coal, including coal-fired boilers and other types of coal-fired burners. It also includes pollution control equipment and on-site preparation equipment. Because pollution control equipment is defined by reference to the IDB provision, rather than the amortization provision, coal cleaning equipment would not be included in that category. Nor would equipment of a coal producer and intermediate coal processor have qualified for the energy tax credit. However, coal cleaning equipment located on-site could have qualified as handling and preparatory equipment.

Unfortunately, the energy tax credit for most items of alternative energy property, including coal usage property, expired at the end of 1982. Accordingly, these incentives are only available for equipment installed in connection with long-term projects which satisfied the "affirmative commitments" requirements at the end of 1982.

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*/ The credit is reduced by 50 percent if the property is financed by Industrial Development Bonds (IDBs). However, as discussed herein, pre-combustion coal cleaning equipment is not eligible for IDB financing. Accordingly, this limitation is not directly relevant.

OPTIONS FOR LEGISLATIVE ACTION

Any legislative action must be undertaken with an understanding of the present political climate. It is appropriate to evaluate alternative tax incentive programs to be pursued in the future as part of an acid rain control strategy program. The Clean Coal Coalition recommends that such tax incentive programs must focus on other available technology options such as coal cleaning and processing, select use of natural gas, and fluidized bed boilers. Any legislative action in this regard should specifically provide incentives for broader deployment of these coal pollution control technologies.

Energy Tax Credit

The energy tax credit provisions which expired at the end of 1982 could be reinstated. In addition, the definition of pollution control equipment for purposes of the tax credit should be revised to track the definition in the rapid amortization provision, rather than the IDB provision. In the alternative, or in addition, a specific tax credit targeted to particular coal cleaning technologies could be enacted. In either case, it would be helpful to extend the credit to public utility property as well as to coal producers and intermediate coal processors.

Industrial Development Bonds

The IDB definition of pollution control equipment could be revised to follow the rapid amortization definition. In the alternative, a special category of exemption could be provided for particular coal cleaning technologies.

Cost Recovery

Utility-owned coal cleaning equipment could be taken out of the ten and fifteen year categories and could be treated as five year property. (There is precedent for such specialized treatment since under current law, certain replacement coal-fired boilers and burners are treated as ten year rather than fifteen year property.)

Other Opportunities

In addition to approaches which parallel existing incentive programs, it is important to attempt to identify new opportunities to encourage coal cleaning activities. For example, in connection with recent proposals to enact an energy consumption tax, an effort could be made to obtain an exemption for coal used in qualifying facilities.

Finally, non-tax alternatives might be considered to satisfy the special financing requirements of public utilities which are not investor-owned in recognition of their unique requirements and operational attributes.

Richard

COLORADO RIVER WILDLIFE COUNCIL

STATE MEMBERSHIP:
Arizona Game and Fish Department
California Department of Fish and Game
Colorado Division of Wildlife
Nevada Department of Wildlife
New Mexico Department of Game and Fish
Utah Division of Wildlife Resources
Wyoming Game and Fish Department

COOPERATING FEDERAL AGENCIES:
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclamation
Corps of Engineers
Environmental Protection Agency
Fish and Wildlife Service
Forest Service
National Park Service

Official Committee File

SENATE COMMITTEE ON
ENERGY AND NATURAL RESOURCES
RECEIVED
JUN 4 1984
WASHINGTON, D.C. 20510

May 15, 1984

Mr. William D. Ruckelshaus
Administrator, Environmental Protection Agency
401 M Street, S.W.
Washington, D.C. 20460

Dear Mr. Ruckelshaus:

The Colorado River Wildlife Council (CRWC) has reviewed the potential problem of "Acid Rain" and the several existing monitoring and evaluation programs at our annual Council meetings in 1982, 1983 and on April 2-3, 1984. Although "Acid Rain" does not appear to be a current problem in the Colorado River Basin, problems resulting from acid deposition have been noted nearly worldwide and potential future acidification in the Colorado River Basin, especially particular areas in high mountain reaches of Colorado, Utah, and Wyoming, is of great concern to the CRWC.

We find that past and present efforts to gather information on acid deposition have employed a variety of methods and have resulted in many separate data sets that are generally not comparable with one another. This seems to be especially true in the western United States. There are several acid deposition monitoring programs currently being conducted within the Colorado River Basin. These programs are not well inter-coordinated and the resulting data they provide will, therefore, likely be of less than maximum value to future analysis. It is vitally important that all data be collected and analyzed according to a single set of procedures.

In our opinion, the Environmental Protection Agency has the strongest responsibility for discharging these mentioned duties and also is best able to work with other organizations such as the U.S. Geological Survey, which is performing good work in the Colorado River Basin. The CRWC strongly supports the efforts of the EPA (Corvallis, Oregon) to coordinate a national program to define the acid deposition problem and provide for a monitoring program. We therefore call upon the EPA to establish and administer a western "Acid Rain" clearing house and coordinating responsibility to the end that this important problem will be ultimately handled in the best manner. We also would like to call upon elected representatives, other concerned organizations and concerned individuals to support a united approach to this wide area problem. Further, we also encourage all groups monitoring acid deposition or conducting related research within the Colorado River Basin to support this EPA effort.

Sincerely,

William A. Molini, Chairman
Colorado River Wildlife Council

WAM/RS/em

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Robert E. Cole
Vice President
Governmental Affairs

KAISER ALUMINUM & CHEMICAL CORPORATION

STATEMENT ON ACID RAIN

Submitted to the
U. S. Senate Committee on
Energy & Natural Resources

May 10, 1984

Kaiser Aluminum & Chemical Corporation is vitally concerned with the acid rain issue. We are pleased the Senate Energy Committee is addressing the subject because energy policy is heavily intertwined in any acid rain discussion. We urge this Committee to look closely at the U.S. energy policy implications of acid rain legislation and actively participate in Senate deliberations on this important issue.

Kaiser Aluminum is an integrated producer of aluminum both in the United States and worldwide. The company is also a major manufacturer of industrial chemicals, refractories and fertilizers. All of these products require substantial quantities of energy in their production. The link to the acid rain issue is particularly focused in the aluminum business where electricity is a major cost ingredient. All the acid rain cleanup proposals put forth to date would require very costly modifications to the coal-burning utility powerplants of the midwest. These modifications would translate directly into higher electricity costs for Kaiser Aluminum and the other customers of those utilities.

Electricity costs represent about one-third of the cost of producing aluminum. On the average it takes 7.5 kilowatt hours of electricity to make a pound of aluminum. Based on 1982 data, the average U.S. cost of electricity for aluminum production was estimated to be 2.4 cents or 24 mills per kilowatt hour (24 mills/kWh). During 1983 this cost climbed even higher. In contrast, our Free World competitors pay an average of 1.7 cents or 17 mills/kWh. Some foreign smelters, including Canadian, pay as little as 3 mills/kWh. Foreign smelters thus already hold a large competitive advantage in terms of this major component of the cost of producing aluminum.

Power costs have a direct impact on worldwide aluminum capacity utilization and, therefore, on jobs. With a 7 mill disadvantage compared to Free World competitors, capacity utilization in the U.S. during the recent recession was 20 percent less than most other aluminum-producing nations in the Free World. During this recession all but the industry's lowest cost facilities were closed or curtailed.

Acid rain control legislation could substantially increase aluminum power costs depending on how the powerplant retrofit costs are allocated. Legislation like S.768 creates a requirement for billions of dollars of capital for scrubbers, but does not specify where the money will come from. Other bills such as HR.5314, would spread a portion of the cost nationally by imposing a new tax on electricity use. HR.5314 proposes a 1 mill/kWh tax on all electric sources with the exception of nuclear. This proposal would also be very damaging to Kaiser Aluminum and the entire U.S. aluminum industry since it would apply to electric power purchases at every smelter in the country. It would be particularly damaging in the Pacific Northwest where the aluminum industry is already under intense offshore competitive pressure due to the high Bonneville Power Administration (BPA) electricity rates. Kaiser operates two major smelters based on BPA power. BPA rates to the aluminum industry are currently 26.8 mills/kWh, or 58 percent higher than the average offshore rate. Any acid rain tax would be a severe blow to the continued operation of the Northwest aluminum capacity. A one mill tax on the Kaiser smelters utilizing BPA power would cause additional curtailments during periods of slack aluminum demand, with an associated loss of employment and loss of other economic benefits to the region. A national electricity tax like the one proposed in HR.5314 could cause significant and unforeseen damage to many industries like ours and to the regional economies where they operate.

Some of the acid rain bills contain provisions that would place a cap on existing SO_2 emissions. This is of great concern to states along the Gulf Coast that derive most of their energy from natural gas. Kaiser Aluminum operates three facilities in the State of Louisiana which consume natural gas as a fuel source. These plants are already in competitive difficulty because of high energy costs. A cap on SO_2 emissions would cancel any consideration of switching to lower cost alternate fuels for these facilities. The result would be a further loss in competitive position and a potential loss of U.S. jobs to foreign competition.

Kaiser Aluminum also owns and operates an integrated aluminum smelter and rolling mill in Ravenswood, West Virginia. The cost of electric power supplied to Ravenswood is approximately in line with the U.S. aluminum smelter average of 24 mills/kWh.

Based on the best information we can obtain, we estimate that electricity prices to Ravenswood would increase by 25 percent or more if a bill like S.768 or HR.5314 were to become law. An increase of this magnitude would seriously damage the competitive position of this facility and cause a loss of jobs not only at Ravenswood, where we employ approximately 2900 people at full operation, but also at fabrication plants in Ohio and other eastern states that receive metal from Ravenswood.

The Ravenswood facilities now constitute Kaiser Aluminum's largest production complex in the world. The smelter portion was reactivated in the latter half of 1983 after an 18-month closedown due to excessive production costs. Kaiser Aluminum and the United Steelworkers of America negotiated major revisions of work practices and other agreements during this period to increase labor productivity and to return the plant to competitive status. Increases in Ravenswood's electricity rates approaching the estimated 25 percent would nullify the labor productivity and other production gains made by Kaiser and the Steelworkers through sacrifices by both labor and management. The future of the Ravenswood smelter is unquestionably linked to the acid rain issue.

In summary, Kaiser is deeply concerned that in an effort to solve one problem, bills like S.768 and HR.5314 would create another problem of intolerable economic proportions. We believe that the scientific uncertainties surrounding acid deposition indicate that the direction of proposals by the Administration, Senator Byrd, Senator Randolph, Congressman Rahall and others for accelerated study is the most appropriate course of action at this time.

5/10/84

ROCKY MOUNTAIN ENERGY

A Subsidiary of
Union Pacific Corporation

James C. Wilson
President

Richard

May 22, 1984

Hon. James A. McClure
368 Dirksen Office Building
Washington, D.C. 20510

Dear Jim:

I want to drop you a short personal note to summarize the testimony I gave before your Committee on April 30, on behalf of the Alliance for Clean Energy. I departed from the formal remarks we filed with the Committee, to summarize the findings of a new study prepared by ICF, Inc. for the Alliance. We think it breaks new ground on several important fronts.

In a nutshell, we asked ICF to determine what levels of SO_2 emissions could be realistically achieved without imposing unnecessarily high costs on utilities or their customers. We also wanted to know what strategies would provide the greatest cumulative SO_2 reductions at the least cost.

I've enclosed a complete copy of the study, but I'd like to emphasize what we think are the highlights.

First, annual SO_2 emissions can be reduced by perhaps as much as 5 million tons within 5 years if utilities are free to choose the most economical compliance methods. If, on the other hand, utilities are forced to use scrubber technology, the practical limit on what can be achieved would be roughly cut in half.

Second, ICF found that the costs climb very fast depending on how high long term SO_2 reduction targets are set--in fact, annualized costs to utilities and their consumers double for every additional 2 million tons.

The ICF study strongly suggests that the best SO_2 reduction strategy would be a phased program that allows the greatest compliance freedom. The study shows that a two-phased program that starts sooner can do more in terms of cumulative SO_2 reductions and at less cost than a more ambitious program on technology.

10 Longs Peak Drive
Box 2000
Broomfield, Colorado 80020
303/469-8544
Telex 45 0221

We also think that a two-phased program is consistent with the policy that calls for continued study to improve the state of knowledge about acid rain. It would allow the Congress to make mid-course corrections as more is learned about acid rain--without committing huge amounts of capital to solve a problem that is now imperfectly understood.

I realize that your Committee hearings were primarily focused on the question of the causal relationship between SO_2 emissions and acid rain. But I think the question of what's feasible and efficient is important too, especially in light of the kinds of acid rain programs that are advancing through the Congress. Since your Committee has special expertise on legislation that affects the cost of energy, I thought you'd be interested in our views on this subject.

Naturally, we'd be glad to answer any questions you or your staff may have about these issues.

Best personal regards.

Sincerely,

Jim